CHAPTER # 07: ELECTROCHEMISTRY

ELECTROCHEMISTRY: The branch of chemistry in which electrical energy is converted into chemical energy and chemical energy if converted into electrical energy is called electrochemistry.

OXIDATION AND REDUCTION:

OXIDATION: A chemical reaction in which oxygen is added, hydrogen is removed and loss of electrons take place is called oxidation.

REDUCTION: A chemical reaction in which oxygen is removed, hydrogen is added and gain of electrons take place is called reduction.

OXIDATION SATE OR OXIDATION NUMBER: The number of charges that an atom will have in a molecule or in a compound is called oxidation state or oxidation number.

RULES FOR ASSIGNING OXIDATION STATES:

1) The oxidation state of any uncombined or free elements is always zero.

Example: The oxidation state of 'Na' and 'Zn' is zero.

2) In simple ions the oxidation state is equal to charge number of the ion.

Example: The oxidation state of K^{+1} is +1 and the oxidation state Ca^{+2} is +2.

3) The oxidation number of every atom in a molecule or in a compound is counted separately and their sum is zero.

Example: In HCl the sum of oxidation states of 'H' and 'Cl' is zero.

4) In complex ion the total sum of oxidation states of atoms is equal to charge on their ion.

Examples: In CO_3^{-2} the sum of oxidation states of 'C' and '3O' is '–2'.

PAGE–NO–161 EXAMPLE–NO–7.3:

A device called Breath Alyzer is used by police to test a person's breath for alcohol. It contains an acidic solution of potassium dichromate $K_2Cr_2O_7$. It is a strong oxidizing agent. Determine oxidation number state of Cr in it.

Oxidation number 'K' = +1

Oxidation number of 'K_2' = 2(+1) = +2

Oxidation number of 'O' = – 2

Oxidation number of 'O_7' = 7(- 2) = – 14

Oxidation number of ‘Cr’ = x

Oxidation number of ‘Cr_2’ = 2(x) = 2x

We know that

Sum of oxidation number’s = 0

(2) + 2(x) + (-14) = 0

2 + 2x – 14 = 0

$2x = 12 \Rightarrow x = \frac{12}{2} = 6$

PAGE–NO–161. EXAMPLE–NO-7.4:

Boric Acid H_3BO_3 is used in eye wash. What is the oxidation state of ‘B’ in this acid.

Boric acid = H_3BO_3

Oxidation Number of ‘H’ = +1

Oxidation number of ‘H_3’ = 3(+1) = +3

Oxidation number of ‘O’ = - 2

Oxidation number of ‘O_3’ = 3(-2) = - 6

Oxidation number of ‘B’ = x

We know that

Sum of oxidation number’s = 0

(3) + (x) + (-6) = 0

3 + x – 6 = 0

x – 3 = 0

x = 3

So, Oxidation number of B = 3

Page–No–162: Self Assessment Ex–No–7.3:

Determine the oxidation number of 'N' in 'NO$_2$' and HNO$_3$, 'S' in 'SO$_2$' and 'H$_2$SO$_4$'.

Oxidation number of N =?

Let oxidation number of 'N' = x

Oxidation number of 'O' = - 2

Oxidation number of 'O$_2$' = 2 (-2) = - 4

We know that

Sum of oxidation number's = 0

(x) + (-4) = 0

x – 4 = 0

x = 4

Oxidation Number of 'N' in NO$_2$ = 5

For SO$_2$

Oxidation number of S =?

Oxidation number of 'S' = x

Oxidation number of 'O' = - 2

Oxidation number of 'O$_2$' = 2 (- 2) – 4

We know that

Sum of oxidation number's = 0

(x) + (-4) = 0

x – 4 = x = 4

Oxidation number of 'S' in SO$_2$ = 4

For H$_2$SO$_4$

Oxidation number of S =?

Oxidation number of 'H' = +1

Oxidation number of 'H_2' = 2 (+1) = +2

Oxidation number of 'O' = - 2

Oxidation number of 'O_4' = 4 (- 2) = - 8

We know that

(+2) + (x) + (-8) = 0

2 + x – 8 = 0

x – 6 = 0 = x = 6

Oxidation number of 'S' in 'H_2SO_4' = 6

OXIDIZING AND REDUCING AGENTS:

In a chemical reaction the reactant that contains the element which gains the electrons (**reduced**) is called oxidizing agent.

In a chemical reaction the reactant that contains the element which losses the electrons (**oxidized**) is called reducing agent.

Example: $2Na + Cl_2 \longrightarrow 2NaCl$

In this reaction 'Na' losses electron therefore it is reducing agent and chlorine gains this electron so it is oxidizing agent.

Page–No–163: Example–No–7.5:

Tungsten is used to make filaments for electric bulbs because it has the highest melting point and electrical resistance. This metal is obtained from tungsten (VI) oxide, WO_3 by reducing it with hydrogen gas. $\mathbf{WO_3 + 3H_2 \longrightarrow W + 3H_2O}$

First we will assign oxidation number's to each atom.

$$\overset{+6\ \ (-2)3}{\mathbf{WO_3}} + \overset{0}{\mathbf{3H_2}} \longrightarrow \overset{0}{\mathbf{W}} + \overset{2(+1)\ \ -2}{\mathbf{3H_2\ O}}$$

Oxidizing Agent: The oxidation number of 'W' decreases therefore 'WO_3' is the oxidizing agent.

Reducing Agent: The oxidation number of 'H' increases therefore 'H_2' is the reducing agent.

Page–No–163: Example–No–7.4:

The torch cell discharges electricity because of an oxidation – reduction that take place between zinc and manganes dioxide. $Zn + 2MnO_2 + H_2O \longrightarrow Zn(OH)_2 + Mn_2O_3$

First we will assign oxidation number's to each atom.

$$\overset{0}{Zn} + \overset{+4\ 2(-2)}{2MnO_2} + \overset{2(+1)\ (-2)}{H_2O} \longrightarrow \overset{+2\ 2(-2)\ 2(+1)}{Zn(OH)_2} + \overset{2(3)\ 3(-2)}{Mn_2O_3}$$

Oxidizing agent: The oxidation number of 'Zn' increases therefore 'Zn' is reducing agent.

Reducing Agent: The oxidation number of 'Mn' decreases therefore MnO_2 is oxidizing agent.

ELECTROCHEMICAL CELLS

The device that convert chemical energy into electrical energy is called electrochemical cell.

TYPES OF ELECTROCHEMICAL CELLS

There are two types of electrochemical cells.

1) Electrolytic cells 2) Galvanic Cells

Electrolytic Cells: An electrochemical cell that uses electrical energy to drive a chemical reaction is called an electrolytic cell.

Galvanic Cells: An electrochemical cell that convert chemical energy into electricity is called a galvanic cell.

NATURE OF ELECTROCHEMICAL PROCESS:

Electrochemical processes are oxidation-reduction reactions. In these reactions chemical energy released by a spontaneous reaction is converted into electrical energy. An electrochemical process always involves the transfer of electrons from one substance to another substance. The electrochemical processes are also called redox reactions because they always involves the transfer of electrons from one body to another body.

ELECTROLYTES: A substance that conducts electricity when it is dissolve in water or in the molten state is called electrolyte.

Examples: NaCl, KCl, HCl are electrolytes.

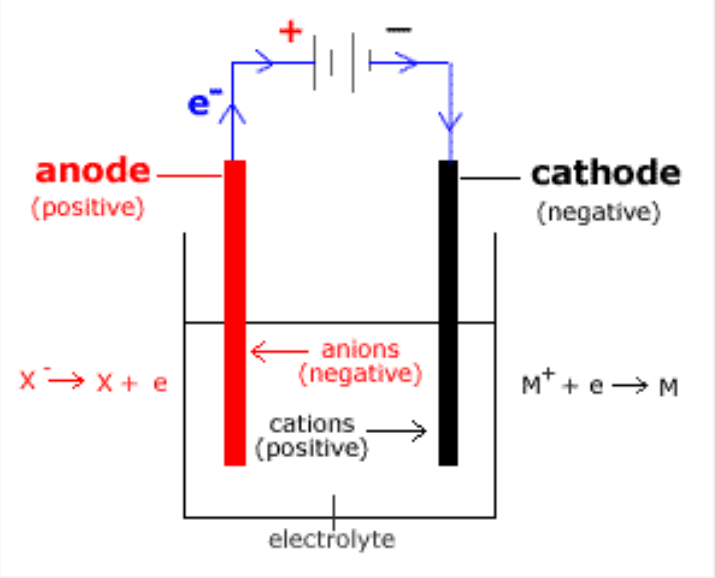
Non – Electrolyte: A substance that cannot conduct electricity when it is dissolve in water or in the molten state is called non – electrolyte.

Examples: Urea, Glucose, benzene are non – electrolyte.

QUESTION: **What is electrolytic cell? Sketch an electrolytic cell labeling cathode and anode. How non – spontaneous reaction is carried out in it**?

Electrolytic Cells: An electrochemical cell in which electrical energy is used to derive a chemical reaction is called electrolytic cell.

Sketch of Electrolytic Cell:



CONSTRUCTION OF ELECTROLYTIC CELL: An electrolytic cell consist of three parts.

a) A vessel containing an electrolyte (MX) b) Two inert electrodes (anode and cathode)

c) A battery which provide electric current

Working of electrolytic cell: In the outer circuit the electrons move from anode to cathode. And in the solution the Cations move towards cathode and anions move towards anode. At anode the anions oxidize by losing electrons. At cathode the cations reduce by gaining these electrons.

At Anode: $X^- \longrightarrow X + 1e^-$

At Cathode: $M^+ + 1e^- \longrightarrow M$

USES OF ELECTROLYTIC CELLS

i) Down's cell is used for the commercial preparation of sodium metal. It also produce chlorine gas as by product.

ii) Nelson's cell is used for the commercial preparation of sodium hydroxide. It also produce chlorine and hydrogen gas as by product.

iii) Electrolytic cells are used for the commercial preparation of calcium and magnesium metals.

iv) Electrolytic cells are used to produce aluminum metal commercially.

v) Electrolytic cells are used for the purification of copper.

vi) Electrolytic cells are used to electroplate metals such as tin, silver nickel on steel.

GALVANIC CELL (DANIEL CELL)

The cell which involve spontaneous redox reaction to generates electricity is called a galvanic cell. It is also called Voltaic cell. The name voltaic is given to this cell because "**Alessandro Volta**" discovered first such cell. It is also called "**Daniel cell**" because an English chemist "**Fredrick Daniel**" Constructed first voltaic cell by using Zinc and copper electrodes.

CONSTRUCTION: A` galvanic cell consist of the following parts.

i) A zinc bar dipped into a 1M $ZnSO_4$ solution.

ii) A copper bar dipped into a 1M $CuSO_4$ solution.

iii) A salt bridge which is invented U – tube. It contains an inert electrolyte such as KCl. Its ions do not react with electrodes. The salt bridge makes the electrical contact between two solutions.

iv) A voltmeter is connected to measure electric current.

PROCEDURE:

A Daniel cell consist of two half cells joined in series. Zinc rod dipped in $ZnSO_4$ solution is called first half cell and copper rod dipped in $CuSO_4$ solution is called second half cell. When circuit is complete then electrons begins to flow from Zinc rod to copper rod. Therefore zinc half cell acts as anode and copper half cell acts as cathode.

REACTIONS IN DANIEL CELL

In Daniel cell the electrons flow from zinc rod to copper rod. Then zinc atoms from the zinc rod go into the solution and loses two electrons. After losing two electrons $\mathbf{Zn^{+2}}$ ions are formed. These two electrons flow in the external circuit. Therefore oxidation occurs at anode. $\mathbf{Cu^{+2}}$ ions present in $\mathbf{CuSO_4}$ solution gain these electrons and as a result 'Cu' is formed. Therefore reduction occurs at cathode.

At Anode: $Zn \longrightarrow Zn^{+2} + 2e^-$

At Cathode: $Cu^{+2} + 2e \longrightarrow Cu$

CORROSION: Corrosion is the process in which a metal reacts with oxygen and moisture in the atmosphere. It is a natural process that converts refined metals to the more stable metal oxides.

EXAMPLE: When iron is placed in moist air then rust is formed on the surface of iron.

RUSTING OF IRON: The formation of rust on the surface of iron is called rusting of iron. It is also called corrosion of iron. Oxygen and water are necessary for rusting of iron. A region of iron that has relatively less moisture acts as anode and the region of iron that has relatively more moisture act as cathode. At the anode oxidation takes place.

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

The $\mathbf{Fe^{+2}}$ ion formed at the anode will move toward cathode with the help of moisture. At the cathode $\mathbf{Fe^{+2}}$ ions further react with oxygen to form rust ($\mathbf{Fe_2O_3.xH_2O}$)

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4) CATHODIC PROTECTION: Cathodic protection is the process in which the metal that is to be protected from corrosion is made cathode and then it is connected to more active metals such as magnesium or aluminum. These active metals act as anode and iron act as cathode. Since magnesium or aluminum are more active than iron so they oxidize themselves and save iron from corrosion. In this way iron is protected from corrosion. Cathodic protection is used to prevent iron and steel structures such as pipes, tanks and Oil rigs.

CHROMIUM PLATING

Chromium plating is a process in which chromium metal is plated on the surface of steel. Since chromium metal does not adhere strongly with the steel. Therefore first of all steel is plated with copper or nickel and then steel is plated with chromium. In this process of chromium plating

chromoum metal is used as anode and chromium sulphate $\mathbf{Cr_2(SO_4)_3}$ is used as electrolyte. The electrolyte ionizes as follows.

$$Cr_2(SO_4)_3 \rightleftharpoons 2Cr^{+3} + 3SO_4^{-2}$$

At Anode: $Cr \rightleftharpoons Cr^{+3} + 3e$

At Cathode: $Cr^{+3} + 3e \rightleftharpoons Cr$

Chromium plated steel is used to make automobile parts.

EXERCISE QUESTIONS PAGE–NO–148

Q–No–2(i): **What is Oxidation State**?

Ans: Oxidation state or oxidation number is defined as the number of charges an atom will have in a molecule or a compound. The elements that show an increase in oxidation number are oxidized and the elements that show decrease in oxidation number are reduced.

Q–No–2(ii): **What is oxidation number of 'Cr' in chromic acid (H_2CrO_4).**

Ans:

Oxidation number of H = 1

Oxidation number of $H_2 = 2(1) = 2$

Oxidation number of Cr = x

Oxidation number of 'O' = - 2

Oxidation number of $O_2 = 4(-2) = -8$

We know that sum of Oxidation number's = 0

$(2) + (x) + (-8) = 0$

$x - 6 = 0$, $x = 6$ so Oxidation number of 'Cr' = 6

Q–No–2(iii): **Identify reducing agent in the following reaction.** $\mathbf{CuO + H_2 \rightarrow Cu + H_2O}$

Assigning oxidation number

$$\overset{+2\ -2}{CuO} + \overset{0}{H_2} \longrightarrow \overset{0}{Cu} + \overset{2(1)\ -2}{H_2O}$$

Oxidizing Agent: The oxidation state of '**Cu**' decrease from +2 to 0 so 'CuO' is an oxidizing agent.

Reducing Agent: The oxidation number of 'H' increases from 0 to +2 so 'H_2' is reducing agent.

Q–No–2(iv): **Write chemical reactions that occur in Nelson's cell**.

At Anode: $2Cl^- \longrightarrow Cl_2 + 2e^-$

At Cathode: $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

Overall reaction: $2Cl^- + 2H_2O \longrightarrow Cl_2 + H_2 + 2OH^-$

Q–No–2 (v): **Why tin plated steel is used to make food cans**?

Ans: Tin plated steel is used to make food can's. Food and beverages industries use tin plated steel cans. This is because the components of food beverages and the preservatives contains organic acid and their salts. These materials can form toxic substances by reacting with iron. These acids and salts are also corrosive. Tin plating is non–poisonous and it also prevent corrosion. Therefore it is used to make food cans.
