

Electrochemistry & Battery Technology

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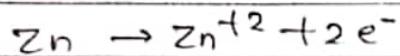
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External supply
of cell

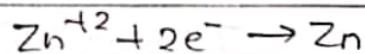
Electrolytic Cell

A cell in which chemical reaction occurs by means of external supply of electric current is known as electrolytic cell. It is used in the purification of metal. It contains two electrode, oxidation takes place at anode and reduction occurs at cathode. For eg:

At anode (oxidation)

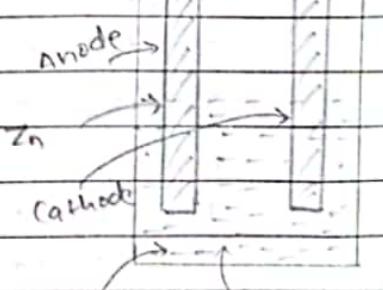


At cathode (Reduction)



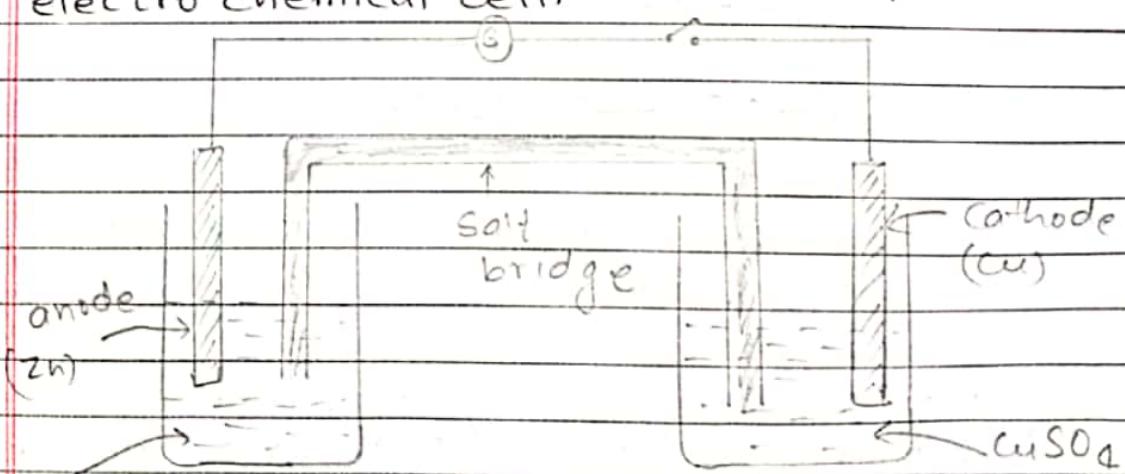
ZnSO₄ Electrolytic Solution

Fig: Electrolytic Cell



Electrochemical Cell

A cell which generates electric current by means of chemical reaction is known as electrochemical cell.



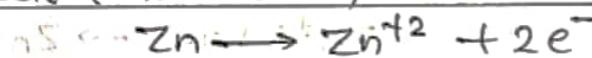
ZnSO₄ Fig: Electrochemical Cell / Galvanic / Voltaic Cell

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It consists of two different electrode dipped in two different electrolyte. These containers are called half cell. Oxidation occurs at anode half cell and reduction occurs at cathode half cell. Two half cells are connected by salt bridge (it contains salt like NH_4NO_3 , NH_4Cl , KNO_3) in agar-agar as a polysaccharides).

When both half cells are connected flow of electron takes place from higher potential to lower potential. The following reaction takes place.

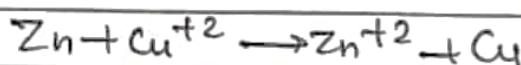
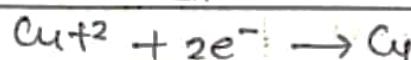
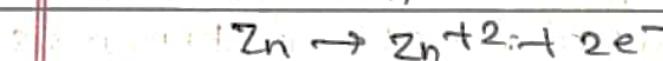
At anode (Oxidation)



At Cathode (Reduction)



Cell Reaction



Difference between electrolytic cell and electrochemical cell

Electrolytic Cell

- i) It converts electrical energy into chemical energy.

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Electrochemical Cell

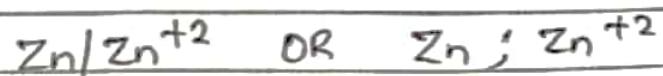
- ii) It converts chemical energy into electrical energy.

ii) It contains same (single) electrode.	ii) It contains two different electrodes.
iii) It contains same electrolytic solution.	iii) It contains two different electrolytic solution.
iv) It does not contain salt bridge	iv) It contains salt bridge
v) It is used in purification of metal	v) It is used in inverter battery, vehicle battery etc.
vi) Anode is positive and cathode is negative	vi) Anode is negative and cathode is positive.
vii) It cannot be represented by cell notation.	vii) It is represented by cell notation.
viii) It does not contain galvanometer/voltmeter.	viii) It contains galvanometer/voltmeter.

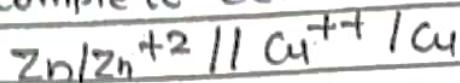
Cell Notation

- Cell notation is represented by:
- i) Anode half cell is represented by writing metal first then metal ion.

For eg:



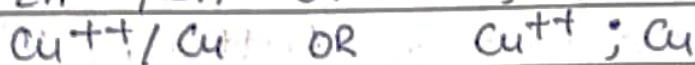
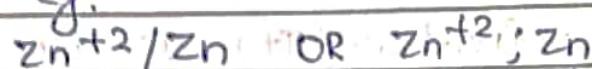
iii) Complete cell notation is represented by



Salt bridge

ii) Cathode half cell is represented by writing metal ion first then metal.

For eg:



Salt Bridge

Salt bridge is U-shaped glass-tube containing inert salt like KNO_3 , NH_4NO_3 , NH_4Cl , KCl etc. solidified in agar-agar electrolyte.

Function of salt bridge

- It maintains electrical neutrality of the solution in two half cell.
- To complete electrical circuit by following ions from one solution to another solution.

Electrode Potential OR Single Electrode Potential

When a metal or electrode like Zinc(Zn), Copper(Cu) etc. dipped into its solution it gets oxidized and metal ions moved into solution. Electron loss from metal gets deposited over the metal surface, as a result electrical double layer is produced.

The potential difference developed between electrode and its ions in the solution due to formation electrical double layer as a result of oxidation and reduction is known as electrode potential or single electrode potential.

-	+	+	-
-	+	+	-
-	+	+	-
-	+	+	-
-	-	+	-
-	-	+	-
-	-	+	-
-	-	+	-

Oxidation

+	-	-	+
+	-	-	+
+	-	-	+
+	-	-	+
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Reduction

Types of Electrode Potential

The potential difference developed as a result of oxidation of electrode is known as oxidation potential.

$E^\circ \rightarrow$ standard electrode potential at $25^\circ C$

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For eg:

$$E^\circ Zn/Zn^{+2} = +0.76 V$$

→ The potential difference developed as a result of reduction of electrode is known as reduction potential.

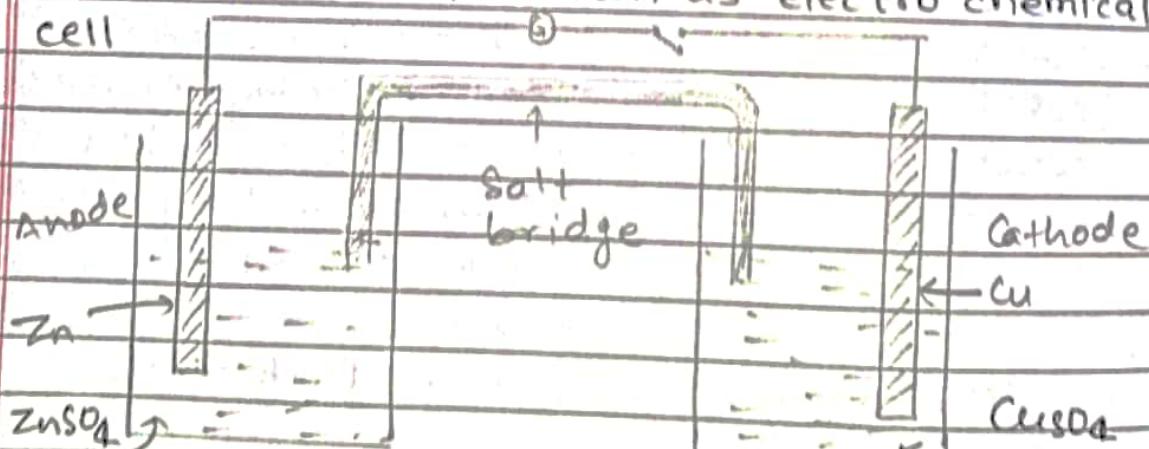
For eg:

$$E^\circ Cu^{+2}/Cu = +0.34 V$$

Assignment

1) What is electrochemical cells, and its uses in different fields.

→ A cell which generates electric current due to chemical reaction is known as electro chemical cell



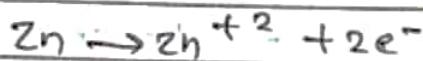
Anode half cell

Cathode half cell

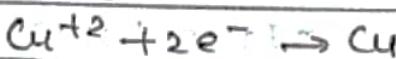
Fig: Electrochemical Cell

Two half cells are connected by salt bridge. When both half cells are connected, flow of electron takes place from higher potential to lower potential.

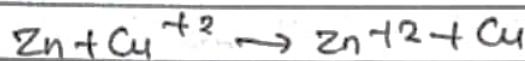
At anode



At cathode



Cell Rxn:



Application of electrochemical cell:-

- i) Electrochemical cells are used in torches, digital watches, corrosion protection etc.
- ii) They use it to analyze a solution for trace amounts of metal ions (production of metal).
- iii) They are used as a source of energy in remote area.
- iv) It is widely used to electroplating by electrolysis
- v) Purification of metal.

2. How do you differentiate between electrochemical cell and electrolytic cell?

Electrolytic Cell	Electrochemical cell
→ It converts electrical energy into chemical energy.	→ It converts chemical energy into electrical energy.
→ It does not contain salt bridge.	→ It contains salt bridge
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→ It contains same electrode.	→ It contains different electrodes.
→ It contains same electrolytic solution.	→ It contains two different electrolytic solution.
→ It is used in purification of metal	→ It is used in battery.
→ Anode is positive & cathode is negative.	→ Anode is negative and cathode is positive.
→ It does not contain galvanometer.	→ It contains galvanometer.

EMF of Cell

The difference between cathode half cell and anode half cell is known as emf of cell. It is denoted by

$$E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

Anode → Oxidation & Cathode → Reduction

The electrode which have lower reduction potential is chosen as anode and cathode is chosen which have higher reduction potential.

Nernst Equation

$$E = E^\circ - \frac{RT}{nF} \ln \left(\frac{\text{Product}}{\text{Reactant}} \right)$$

Where

R → Universal Gas Constant

$$= 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

T = Absolute Temperature

$$= (t^\circ \text{C} + 273) \text{ K}$$

n = Number of mole of electron

F = Faraday's constant

$$= 96500 \text{ C}$$

$$\ln = 2.303 \log$$

At 25°C:

$$E = E^\circ - \frac{0.0591}{n} \log \left(\frac{\text{Product}}{\text{Reactant}} \right)$$

Q.1 From the given electrode potential value answer the following questions.

i) Write the electrode reaction.

ii) Write the cell reaction

iii) calculate the emf of the cell at 298K

$$E^\circ \text{ Zn}^{+2}/\text{Zn} = -0.76 \text{ V}$$

$$E^\circ \text{ Ag}^+/\text{Ag} = +0.80 \text{ V}$$

$$[\text{Zn}^{+2}] = 0.01 \text{ M}$$

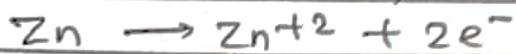
$$[\text{Ag}^+] = 0.1 \text{ M}$$

Soln,

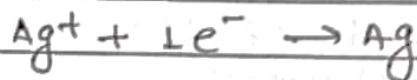
Since, the reduction potential of Zn is less than Ag. So, Zn is chosen as anode and Ag is chosen as cathode.

(i) Electrode Reaction

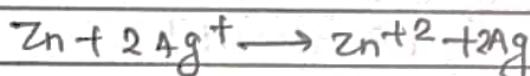
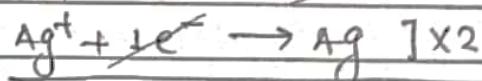
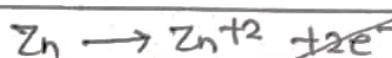
At anode (oxidation)



At Cathode (Reduction)



(ii) Cell Reaction



(iii) EMF of cell at 298 K

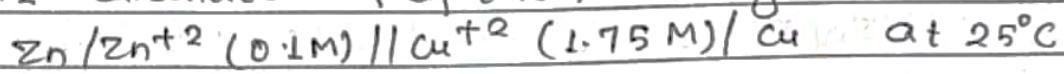
$$E = E^\circ - 0.0592 \log \frac{[\text{Product}]}{[\text{Reactant}]}$$

$$= [+0.80 - (-0.76)] - \frac{0.0592}{2} \log \frac{[0.01]}{[0.1]^2}$$

$$= +1.56 - 0.02955 \log 1$$

$$\therefore E = +1.56 \text{ V}$$

Q.2 Calculate emf of the following cell



$$E^\circ \text{Zn}/\text{Zn}^{+2} = +0.76 \text{ V}$$

$$E^\circ \text{Cu}^{+2}/\text{Cu} = +0.34 \text{ V}$$

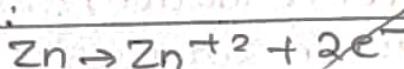
Sol? -

Reduction potential of Zn is

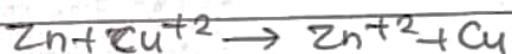
$$\text{Zn}^{+2}/\text{Zn} = -0.76 \text{ V}$$

Since, the reduction potential Zn < Cu. So, Zn is anode and Cu is cathode.

At anode (oxidation):



At cathode (Reduction): $\text{Cu}^{+2} + 2e^- \rightarrow \text{Cu}$



Now,

$$E = E^\circ - \frac{0.0591}{n} \log \frac{\text{[Product]}}{\text{[Reactant]}}$$

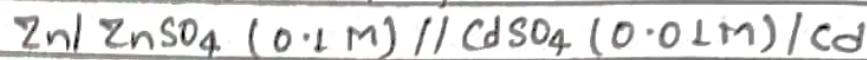
$$= [+0.34 - (-0.76)] - \frac{0.0591}{2} \log \frac{[0.1]}{[1.75]}$$

$$= +1.1 - 0.02955(-1.24)$$

$$= +1.1 + 0.036$$

$$\therefore E = +1.136 \text{ V}$$

Q.3 Calculate emf of the cell



$$E^\circ \text{ Zn}^{+2}/\text{Zn} = -0.76 \text{ V}$$

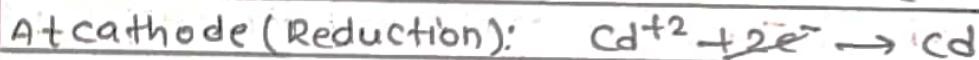
$$E^\circ \text{ Cd}/\text{Cd}^{+2} = +0.40 \text{ V}$$

Sol:

$$\text{Cd}/\text{Cd}^{+2} = +0.40 \text{ V}$$

$$\text{Cd}^{+2}/\text{Cd} = -0.40 \text{ V}$$

Since, reduction potential of $\text{Zn} < \text{Cd}$. So, Zn is chosen as anode whereas Cd as cathode.



$$E = E^\circ - \frac{0.0591}{2} \log \frac{\text{[Product]}}{\text{[Reactant]}}$$

$$= [-0.40 - (-0.76)] - \frac{0.0591}{2} \log \frac{[0.1]}{[0.01]}$$

$$= +0.36 - 0.02955 \times 1$$

$$\therefore E = +0.3304 \text{ V}$$

Daniel Cell

A cell which generates electronic current by means of chemical reaction is known as electrochemical cell.

The electrochemical cell in which anode is made up of zinc and cathode is made up of copper and dipped in zinc sulphate and copper sulphate solution anode and cathode respectively then this type of cell is called daniel cell.

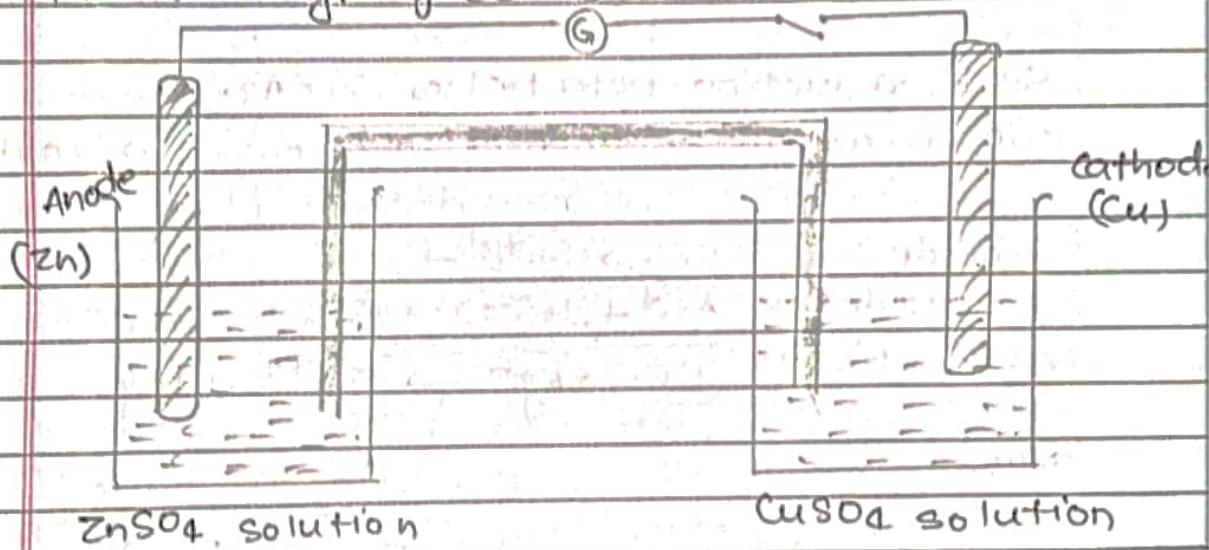
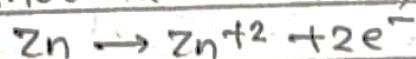
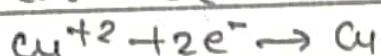


Fig: Daniel cell

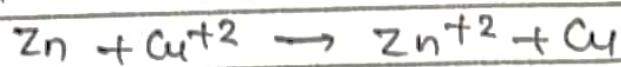
At anode (Oxidation)



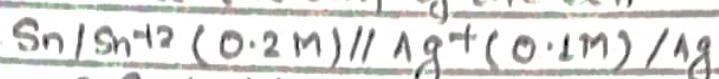
At cathode (Reduction)



Cell Reaction



Q.4. Calculate the emf of the cell



$$E^\circ \text{ Sn/Sn}^{+2} = +0.14 \text{ V}$$

$$E^\circ \text{ Ag}/\text{Ag}^+ = -0.80 \text{ V}$$

Sol:-

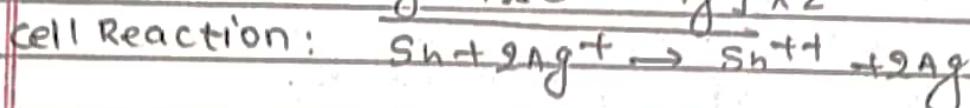
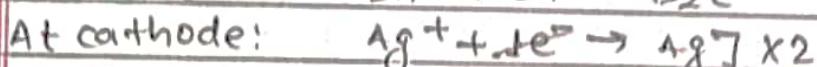
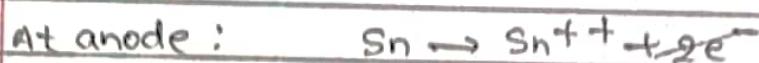
$$E^\circ \text{ Sn/Sn}^{+2} = +0.14 \text{ V}$$

$$E^\circ \text{ Sn}^{+2}/\text{Sn} = -0.14 \text{ V}$$

$$E^\circ \text{ Ag}/\text{Ag}^+ = -0.80 \text{ V}$$

$$E^\circ \text{ Ag}^+/\text{Ag} = +0.80 \text{ V}$$

Since, reduction potential of $\text{Sn} < \text{Ag}$. So, 'Sn' is chosen as anode and 'Ag' is chosen as cathode



Now,

$$E = E^\circ - 0.0591 \log \frac{\text{Product}}{\text{Reactant}}$$

$$= \{+0.80 - (-0.14)\} - 0.02955 \log \frac{(0.2)}{(0.1)^2}$$

$$= +0.94 - 0.02955 \times 1.301$$

$$\therefore E = +0.901 \text{ V}$$

Electrochemical Series (OR Activity Series)

The systematic arrangement of elements or electrodes in the order of increasing reduction potential or decreasing oxidation potential is known as electrochemical series. It is also known as activity series. Example:

Element	Electrode	E°_{red} at 25°C (Volt)
Li	Li^+/Li	-3.05
K	K^+/K	-2.95
Ba	Ba^{+2}/Ba	-2.90
Ca	Ca^{+2}/Ca	-2.87
Na	Na^+/Na	-2.71
Mg	Mg^{+2}/Mg	-2.37
Zn	Zn^{+2}/Zn	-0.76
Fe	Fe^{+2}/Fe	-0.44
H	$2\text{H}^+/\text{H}_2$	0.0
Cu	Cu^{+2}/Cu	+0.34
Au	Au^{+3}/Au	+1.5

Application of electrochemical series

(i) Prediction of anode and cathode

The electrode which have less reduction potential is chosen as anode and higher reduction potential is chosen as cathode.

For e.g.:

$$E^\circ \text{ Zn}^{+2}/\text{Zn} = -0.76 \text{ V}$$

$$E^\circ \text{ Fe}^{+2}/\text{Fe} = -0.44 \text{ V}$$

Since, the reduction potential of Zn is less than Fe. So 'Zn' is chosen as anode.

(ii) Calculation of emf of cell

The emf of cell is calculated by:

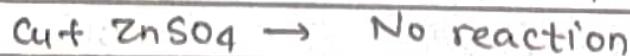
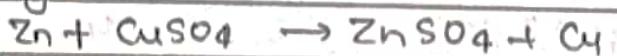
$$E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

$$E^\circ = E^\circ_{\text{Reduction}} - E^\circ_{\text{Oxidation}}$$

(iii) To predict whether a given metal can displace another metal from metal solution

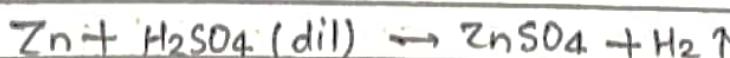
A metal which have lower reduction potential can displace another metal from their solution.

For e.g.:



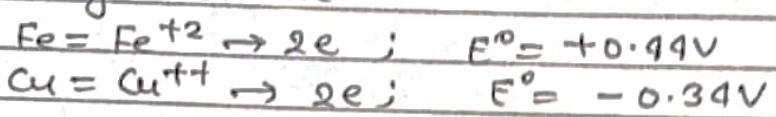
(iv) To predict whether a given metal can displace hydrogen gas from mineral acid

Those metal which are lying above hydrogen in electrochemical series can displace hydrogen gas from mineral acid. For e.g.:



N) To predict the feasibility of the cell
 Positive emf produced by the cell shows the feasibility of the reaction or spontaneity of the reaction.

Q.5 Calculate the emf of cell at 20°C from following electrode.



Sol?

$$T = 20^\circ\text{C}$$

$$= (20 + 273)\text{K}$$

$$= 293\text{K}$$

$$E^\circ \text{ Fe/Fe}^{+2} = +0.44\text{V}$$

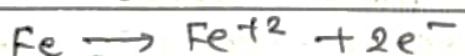
$$E^\circ \text{ Fe}^{+2}/\text{Fe} = -0.44\text{V}$$

$$E^\circ \text{ Cu/Cu}^{+2} = -0.34\text{V}$$

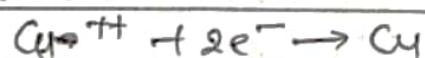
$$E^\circ \text{ Cu}^{+2}/\text{Cu} = +0.34\text{V}$$

Since, Reduction potential of Fe < Cu. So, Fe is chosen as anode whereas Cu as a cathode.

At anode



At Cathode



Now,

$$E = E^\circ - \frac{RT}{nF} \ln [\text{Product}]$$

$$[\text{Reactant}]$$

$$= +0.34 - (-0.44) - \frac{8.314 \times 293 \times 2.303 \log \left(\frac{1}{1} \right)}{2 \times 96500}$$

$$= +0.78 - 0$$

$$= +0.78 \text{ V}$$

Corrosion

Corrosion is a natural phenomenon, it's a redox process in which a metal or alloy get oxidized by oxygen or moisture.

The phenomenon of formation of amorphous brown layer of hydrated oxide of iron on its surface in the presence of moisture is called rusting.

Types of Corrosion

There are two types of corrosion:

(i) Dry Corrosion

The corrosion that occurs by direct chemical reaction of metal surface with certain agents like HCl , H_2SO_4 , CH_3COOH , SO_2 , H_2S , NH_3 etc is known as dry corrosion/ chemical corrosion/direct corrosion.

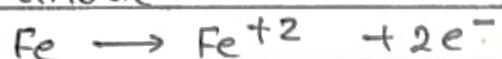
(ii) Wet Corrosion (Electrochemical Corrosion)

The corrosion of metal that occurs in aqueous environment is called electrochemical corrosion or wet corrosion. Foreg: rusting of water pipe, rusting of iron etc.

Electrochemical Theory of Rusting

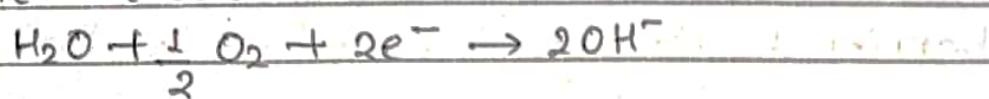
Among various types of theory electrochemical theory of rusting is more scientific. According to this theory, rusting of iron is electrochemical process in which chemical reaction is occurred by flow of electrons from metal, metal act as anode which gets oxidized and dissolved in solution.

At anode

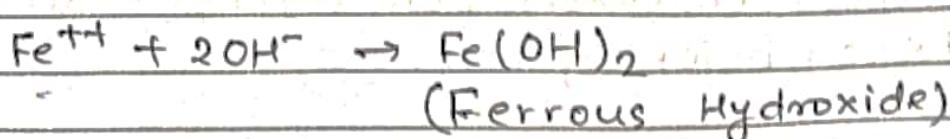


Thus, released electron moves into solution and combines with oxygen.

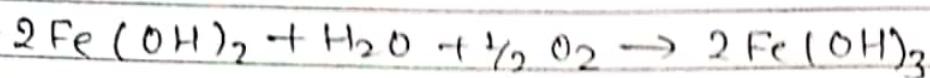
At cathode



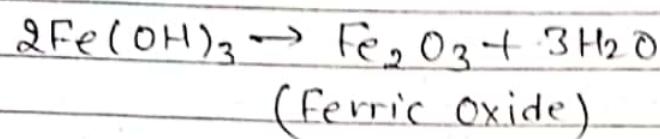
Fe^{+2} ion from anode and OH^- from cathode migrates together to form Fe(OH)_2



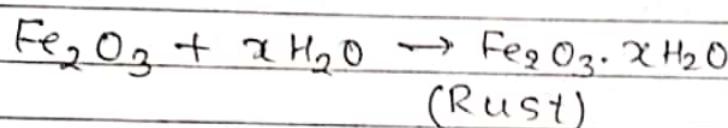
Fe(OH)_2 get oxidized into Fe(OH)_3



Thus, produced Fe(OH)_3 is unstable and decomposed into Fe_2O_3 .



Ferric oxide absorb moisture and forms hydrated scale which is known as rust.



Prevention of Corrosion

i) Protective Coating

Metal can be protected from rusting by coating the surface of metal by oil, grease, metallic thin film etc which can act as barrier between metal surface and atmosphere.

ii) Application of Inhibitor

In this process, metal is treated with certain solution like potassium chromate (K_2CrO_4), phosphoric acid (H_3PO_4) which inhibit the corrosion of iron.

iii) Galvanization

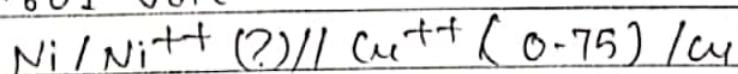
The coating of iron surface with thin uniform layer of zinc is known as galvanization. It prevents metal from corrosion by separating metal surface and corrosive atmosphere.

iv) Cathodic Protection

This is the most important method of prevention of corrosion. In this method iron is kept in the contact with electro positive metal which acts as anode and iron becomes cathode. The electropositive metal undergoes corrosion prior than iron. Such types of protection is known as sacrificial protection.

Assignment

1) What is the concentration of Ni^{2+} ions of the cell at 25°C . If the emf of the cell is 0.601 volt.

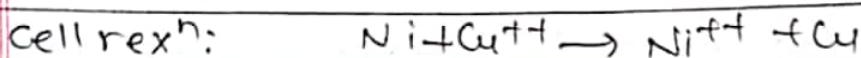
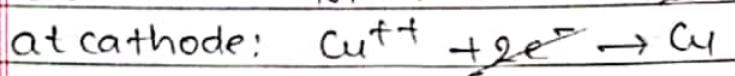


$$\text{Ni}^{2+}/\text{Ni} = -0.25\text{ V}$$

$$\text{Cu}^{2+}/\text{Cu} = +0.34\text{ V}$$

Sol:

Reduction potential is $\text{Ni} < \text{Cu}$. So, Ni is anode and Cu is cathode.



$$E = E^\circ - \frac{0.0591}{n} \log \frac{\text{[Product]}}{\text{[Reactant]}}$$

✓ $0.601 = \{ + 0.34 - (-0.25) \} - \frac{0.0591}{2} \log \frac{\text{[Product]}}{\text{[6.75]}}$

✓ $0.601 = + 0.59 - 0.02955 \log \frac{\text{[Product]}}{\text{[6.75]}}$

✓ $0.601 - 0.59 = - 0.02955 \log \frac{\text{[Product]}}{\text{[0.75]}}$

✓ $0.011 = - 0.02955 \log \frac{\text{[Product]}}{\text{[0.75]}}$

✓ $\log \frac{\text{[Product]}}{\text{[0.75]}} = \frac{0.011}{-0.02955}$

✓ $\log \frac{\text{[Product]}}{\text{[0.75]}} = -0.3722$
Antilog (-0.3722)

✓ $\log \text{[Product]} - \log [0.75] = -0.3722$

✓ $\log \text{[product]} = -0.3722 + \log (0.75)$

✓ $\log \text{[product]} = -0.3722 + (-0.1249)$

✓ $\log \text{[product]} = \cancel{-0.2473} - 0.4971$

✓ $\text{[Product]} = \text{antilog} (-0.2473)(-0.4971)$

✓ $\therefore \text{[Product]} = \cancel{0.00} \underline{\underline{0.31}}$

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Battery.

The term battery is used for a combination of few number of cell of the same type. If a number of cell are connected in series then the arrangement is called battery.

A commercial battery have following characteristics:-

- (i) It should be compact in size.
- (ii) It should be light
- (iii) It should give constant voltage and should not vary during use.
- (iv) It should have long life.

Types of Commercial Battery

1) Primary Cell

Primary cells are those cell in which redox reaction occurs once and then becomes dead after some time. They cannot be recharged and use again. For example: dry cell, mercury cell, cadmium cell

Construction of Dry Cell

Dry cell is a compact form of Lechlanche Cell after the name of discoverer George Lechlanche in 1866. It consists of cylindrical zinc container which acts as anode. A graphite cathode is placed at the centre, which acts as cathode. The space between

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anode and cathode is packed with ammonium chloride and zinc chloride paste. When graphite rod is surrounded by $MnO_2 + C$ which is shown in fig. The graphite rod is fitted with metal cap. the zinc container is covered with card board paper which protects from atmosphere.

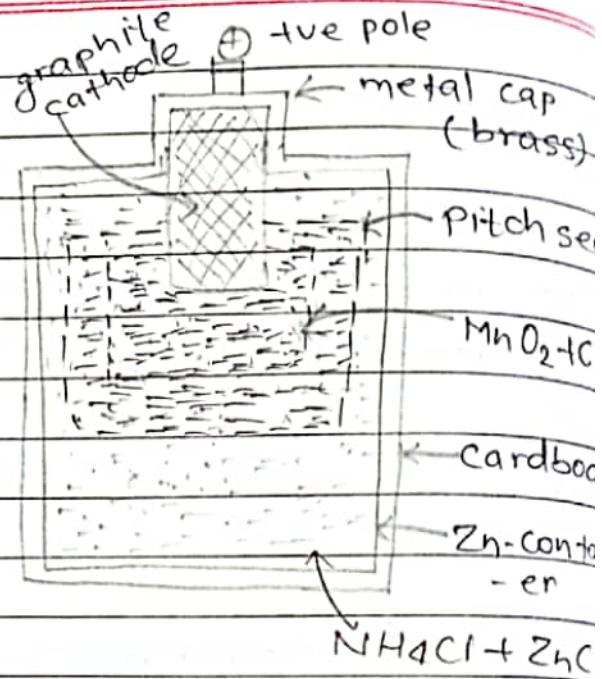
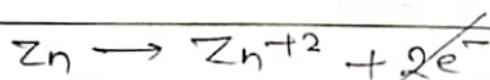


Fig: dry cell.

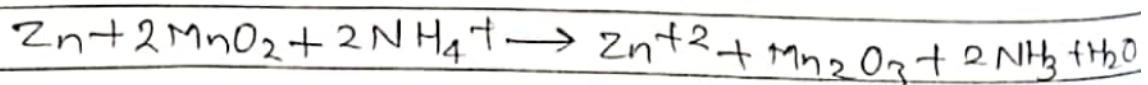
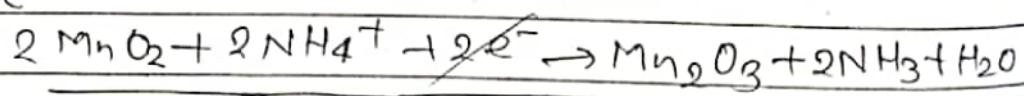
It shows that zinc acts as anode and graphite acts as cathode while paste of ammonium chloride and zinc chloride in zinc cylinder and $MnO_2 + C$ surrounding graphite acts as electrolyte.

The following cell reaction takes place.

At anode



At cathode



The voltage of dry cell is ranges from 1.25 to 1.5 V

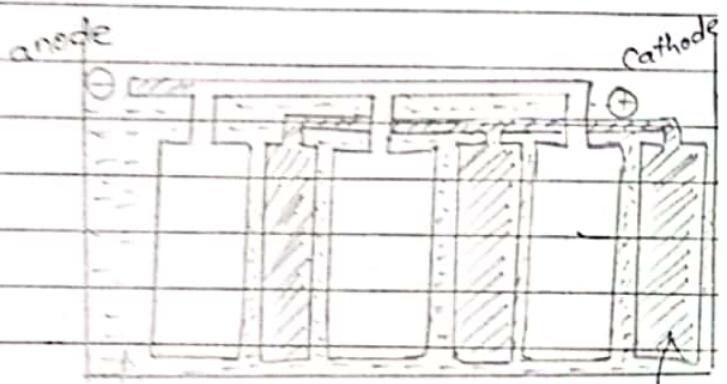
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2) Secondary cell

Secondary cells are those cells which can be recharged and used again and again. They are also called rechargeable battery or storage battery. For eg. Lead-acid battery, Nickel-Cadmium battery (smart watch), Lithium-Ion battery (mobile, laptop), Sodium-ion battery etc. They are used in vehicles, automobiles etc.

Construction of Lead storage battery

It consists of six cells which are connected in series to get twelve volt (12V) battery. Each cell produces 2V in each cell. The

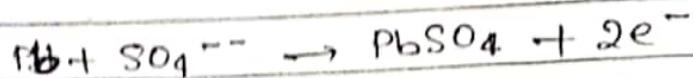


dil. H_2SO_4 (lead plate) Filled with PbO_2
Fig: Lead storage battery.

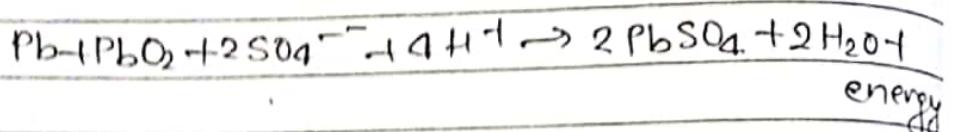
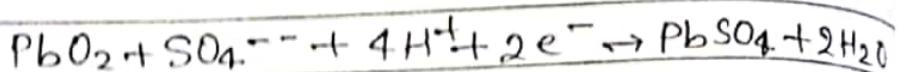
The electrolyte is the aqueous solution of sulphuric acid which is 38% by mass. To increase the current output each cell, the cathode and anode plate are connected in parallel combination i.e. anode to anode and cathode to cathode.

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At anode:



At Cathode:



Zinc-Copper (Zn-Cu) Cell (Daniel cell)

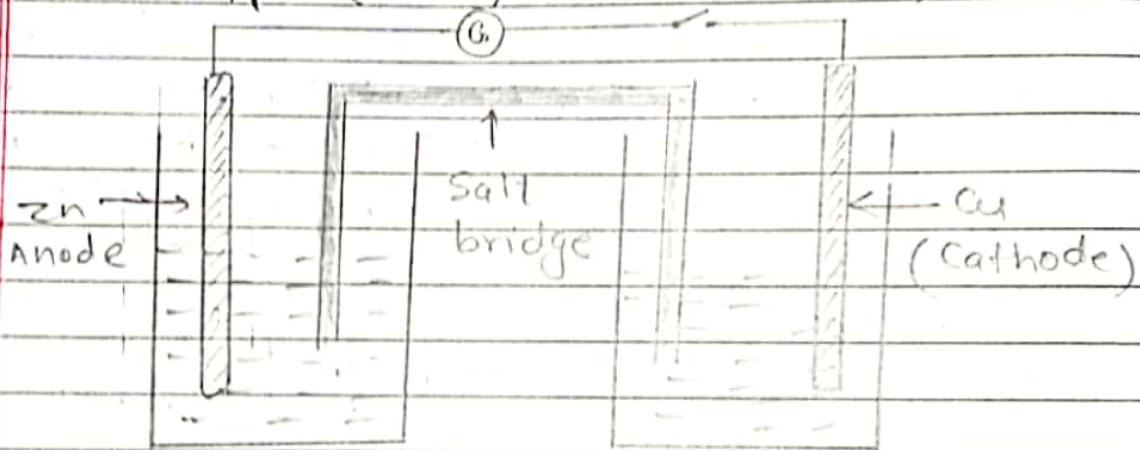
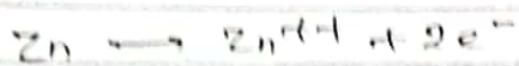


Fig: Zn-Cu Cell

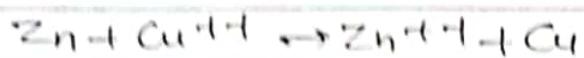
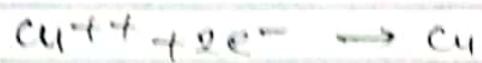
In Zn-Cu cell, zinc acts as an anode which is dipped in ZnSO_4 solution and copper acts as cathode which is dipped in CuSO_4 solution. Oxidation occurs at anode and reduction occurs at cathode. Both cells are connected with salt bridge. A salt bridge is a U-shaped glass tube containing neutral electrolyte KNO_3 , NH_4NO_3 , KCl in agar-agar. Both cells are externally connected with galvanometer, which is shown in above figure. Following reaction occurs:

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At anode:

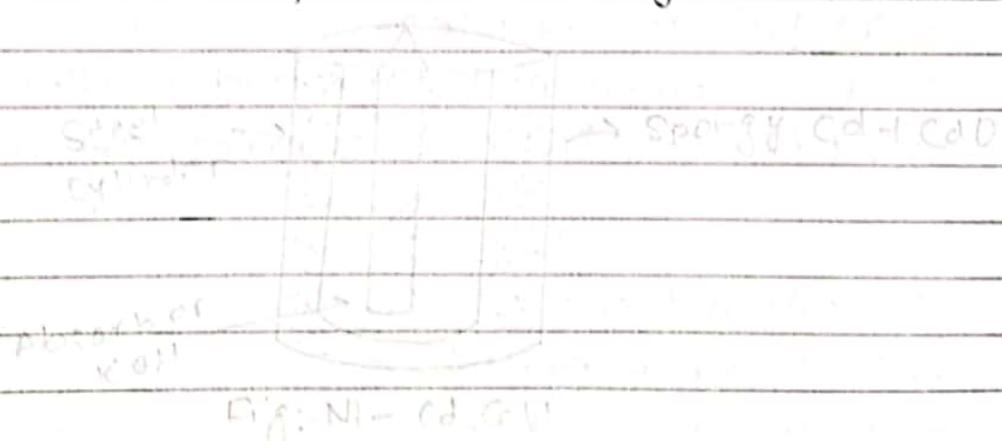


At cathode:

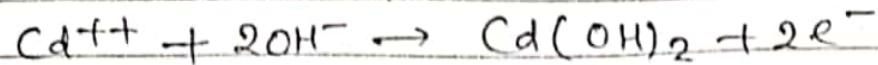
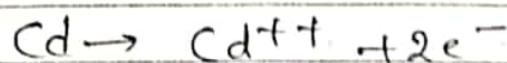


Ni-Cd Cell

It is also called rechargeable battery. It has longer life than lead storage battery. It is more expensive, smaller and lighter. It is a portable battery. In Ni-Cd cell, anode is cadmium and cathode is nickel oxide (NiO_2). The electrolyte is the solution of potassium hydroxide.



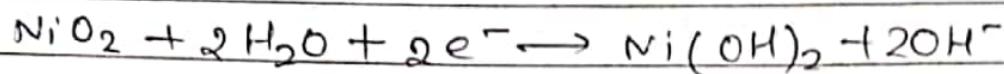
Following reaction takes place:
 * Cadmium is oxidized to Cd^{2+} and combines with OH^- to form $\text{Cd}(\text{OH})_2$



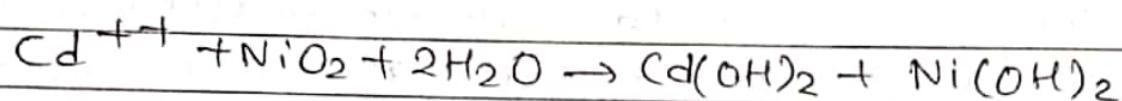
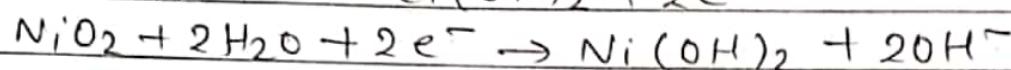
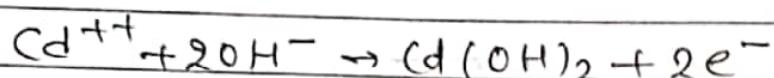
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At cathode

NiO_2 gains electrons and combines with water to form Ni(OH)_2



Cell reaction.



Advantages:

- It has longer life.
- It is compact, lighter and smaller in size.
- It is used in high current application.

Disadvantages

- It is very expensive.
- Cadmium is highly toxic.
- It has high self discharge rate and need to recharge

Uses

- It is used in electronic calculator, transistors, smart watch & other small tools.

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- It is used in communication equipment.
- It is widely used in aircraft and space satellites.

Lithium-Ion Battery

It is another type of rechargeable battery. It is a solid state battery because instead of liquid or paste of electrolyte, solid electrolyte is used.

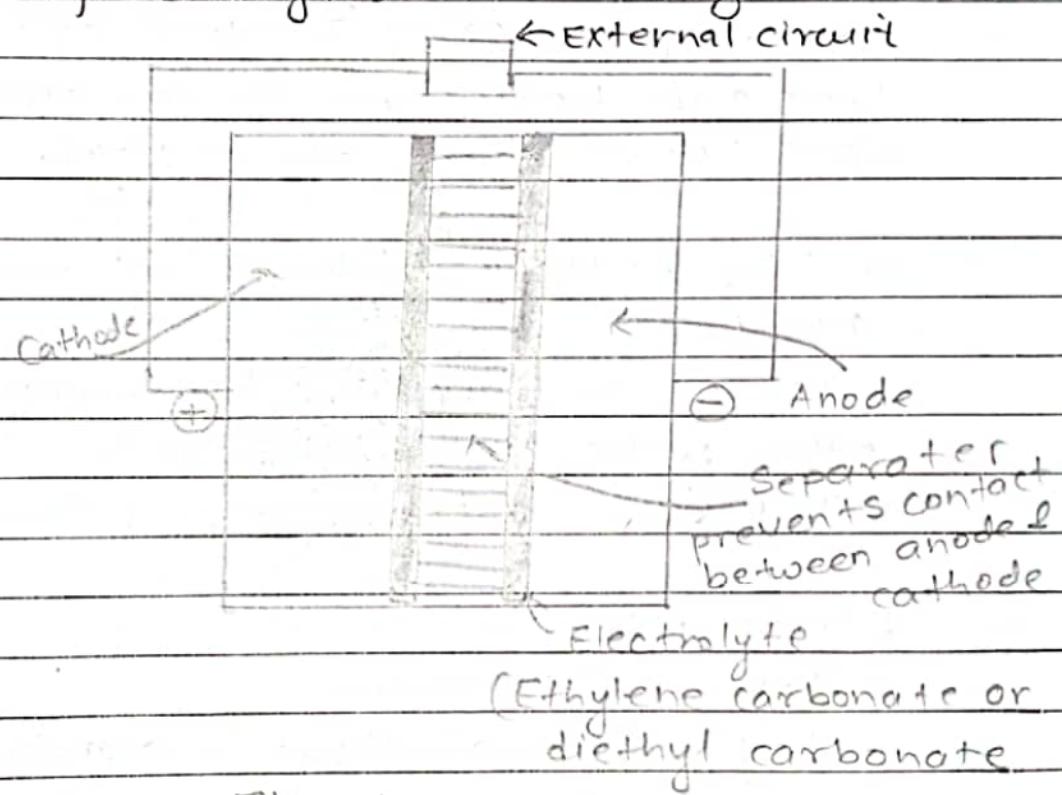
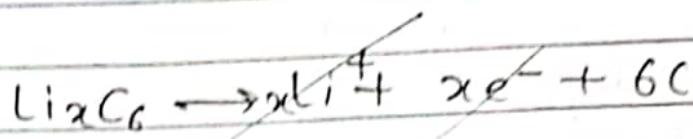


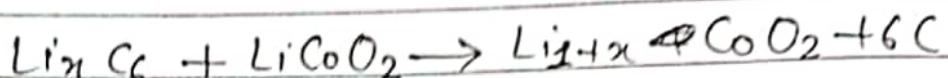
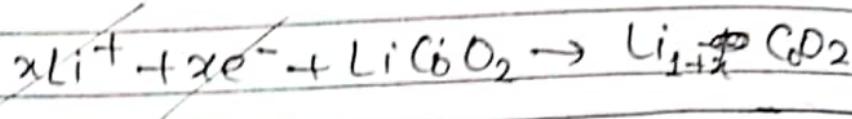
Fig: Li-Ion Battery

A positive electrode is made up of Li-Cobalt oxide or Lithium magnese oxide (LiMnO_4) and negative electrode is made with special carbon graphite (C_6). A separator is a fine pores polymer film(layer). Electrolyte is ethylene carbonate or diethyl carbonate. The following reaction takes place:

At anode:



At cathode:



Advantages:

→ Lithium-ion battery can store 130 Watt hour electricity in 1 kg of battery as compare to Lead acid battery which can store only 23 watt hours electricity in 1 kg.

→ Li-Ion battery produces high voltage about 4 volt.

→ Li-Ion battery have high energy density than other rechargeable batteries.

→ They have fast charge and slow discharge.

Disadvantages

→ They are expensive.

→ They are not available in standard cell type.

Application:

→ They are used in mobile, laptop, aerospace.

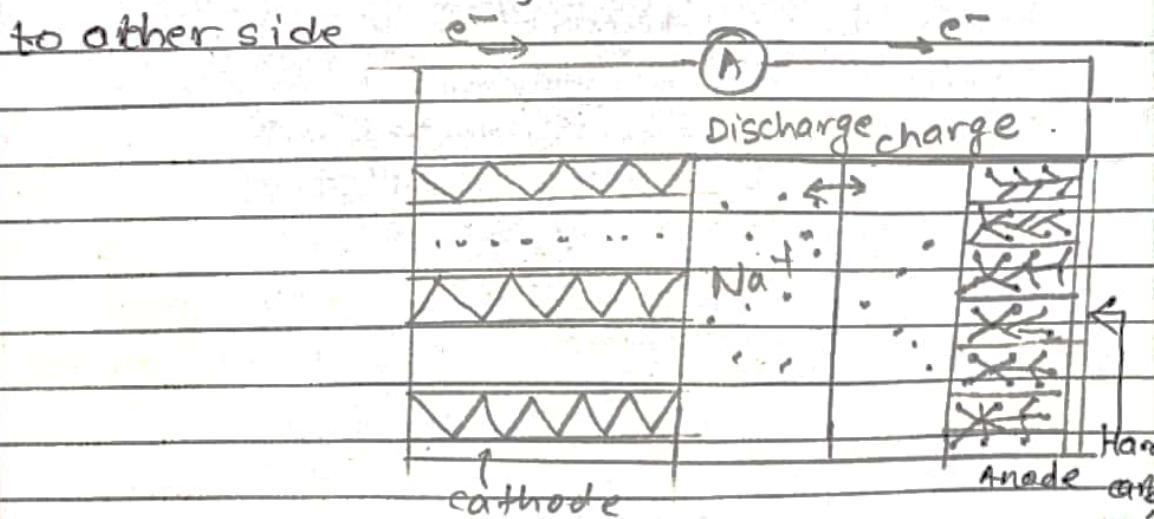
→ They are used in cardiac pacemaker

→ They are used in telecommunications, portable radios and in camera.

Sodium-Ion Battery

A sodium-ion battery is an energy storage system based on electrochemical charge/discharge reaction takes place between cathode composed of sodium and anode made up of carbon. The electrodes are separated by some pores materials which allow ionic flow between cathode and anode. Both are immersed in electrolyte made up of aqueous sodium sulphate (Na_2SO_4). When the battery is being charged, sodium atoms in the cathode release electrons to the external circuit and becomes ions, which migrates through the electrolyte towards the anode, where they combine with electrons from the external circuit.

When a sodium ion battery is discharged, the anode releases sodium ions to the cathode and flow of electrons from one side to other side



Reserve Battery

In this battery, one of the key component is stored separately, and is incorporated into battery when required; reserve batteries are used. For eg: Mg-AgCl battery. They are activated by adding sea water. These batteries have long self-life. Another example is Zinc-air-batteries, where the cell is sealed until use, the seal is removed to admit air and activate the cell when needed.

Substitution Reaction

The reaction in which an atom or group of atom is replaced by another atom or group of atom is known as substitution reaction.

Nucleophilic Reaction

The substitution reaction in which a weaker nucleophile is replaced by stronger nucleophile is known as nucleophilic substitution reaction.

For eg:



substrate Nucleophile product leaving group.

Types of nucleophilic substitution reaction

(i) S_N^1 Reaction (Unimolecular Nucleophilic Substitution Reaction)

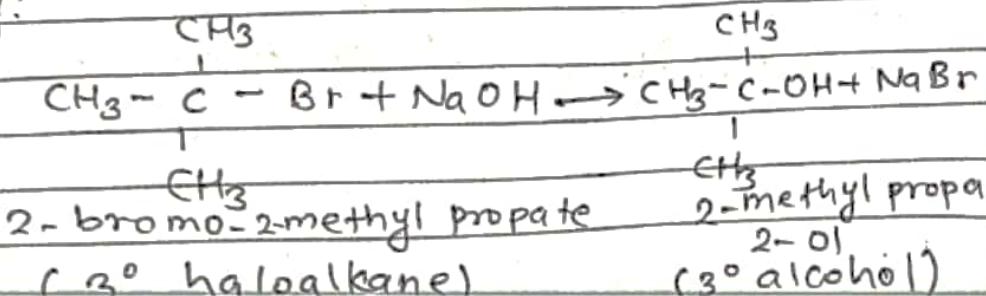
The nucleophilic substitution reaction whose rate depends upon concentration of substrate (haloalkane) molecule is only is known as S_N^1 reaction. It follows first order kinetics i.e.

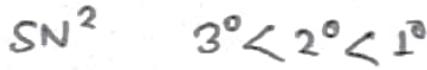
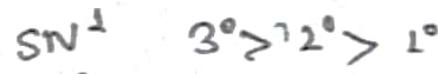
Rate \propto [substrate]

Rate = k [substrate]

Where, $K \rightarrow$ Rate constant.

For eg:





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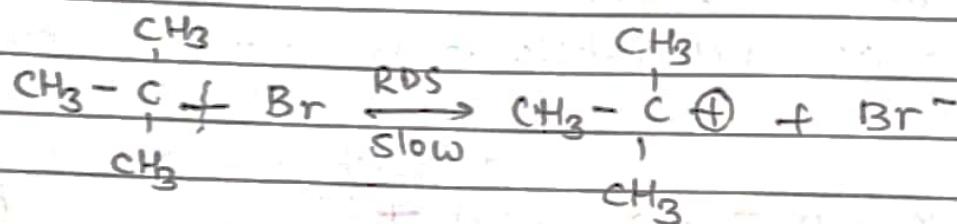
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Mechanism of $S\bar{N}^2$ Reaction

$S\bar{N}^2$ reaction is completed in two step:

Step-1:

In Step-1, tertiary butyl bromide undergoes heterolytic bond fission to give carbocation and halide ion which is very slow step and rate determining step.

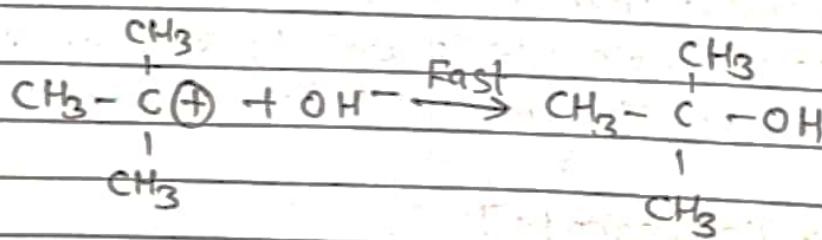


Tertiary-butyl
bromide

Tertiary-butyl carbocation

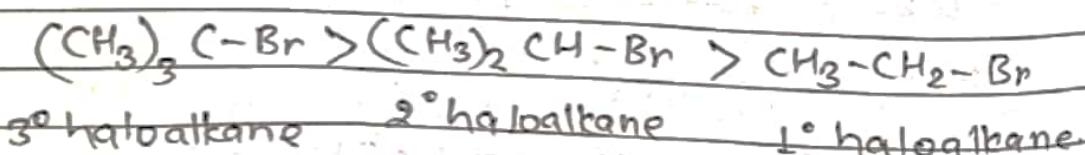
Step-2

The carbocation is highly reactive and react with nucleophile to give product

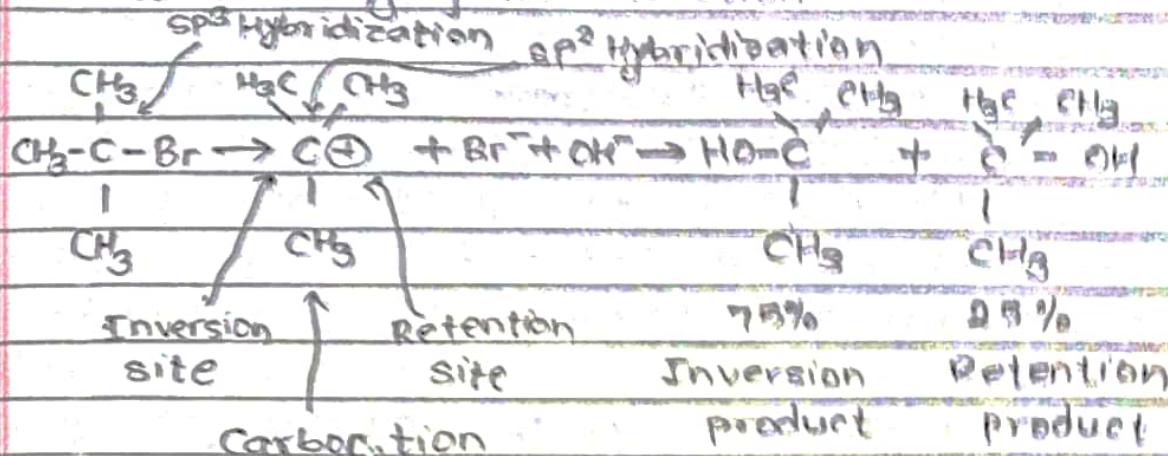


2-Methyl propan-2-ol

The reactivity order of $S\bar{N}^1$ reaction is



Stereochemistry of $\text{S}^{\text{N}}\text{I}$ Reaction



$\text{S}^{\text{N}}\text{I}$ reaction proceeds by the formation of intermediate carbocation which has trigonal planar structure. The stereochemistry of $\text{S}^{\text{N}}\text{I}$ reaction proceeds with a partial racemization and inversion.

The nucleophile Br^- is present on the retention site and blocks the path of attack of nucleophile (OH^-) but inversion site is free for the attack of nucleophile. There is no any hindrance so inversion product is greater than retention product.

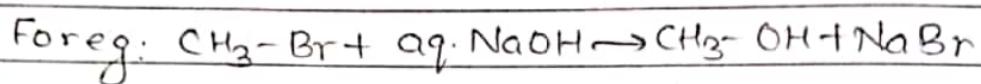
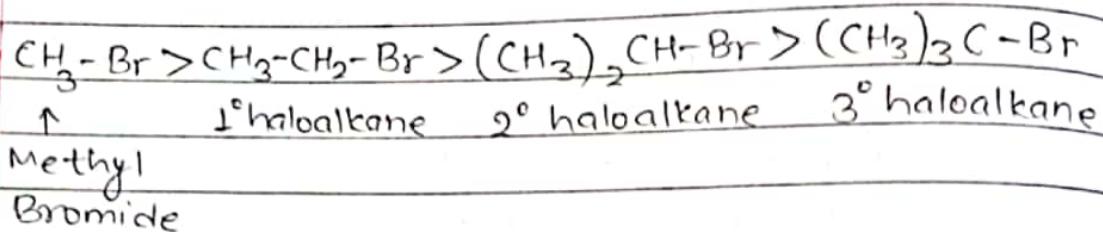
(ii) $\text{S}^{\text{N}}\text{I}$ Reaction (Bimolecular Nucleophilic Substitution Reaction)

The nucleophilic substitution reaction whose rate depends upon both the concentration of substrate and nucleophile is known as $\text{S}^{\text{N}}\text{I}$ reaction. It follows second order kinetics.

i.e. Rate \propto [substrate] [Nucleophile]
Rate = k [substrate] [Nucleophile]

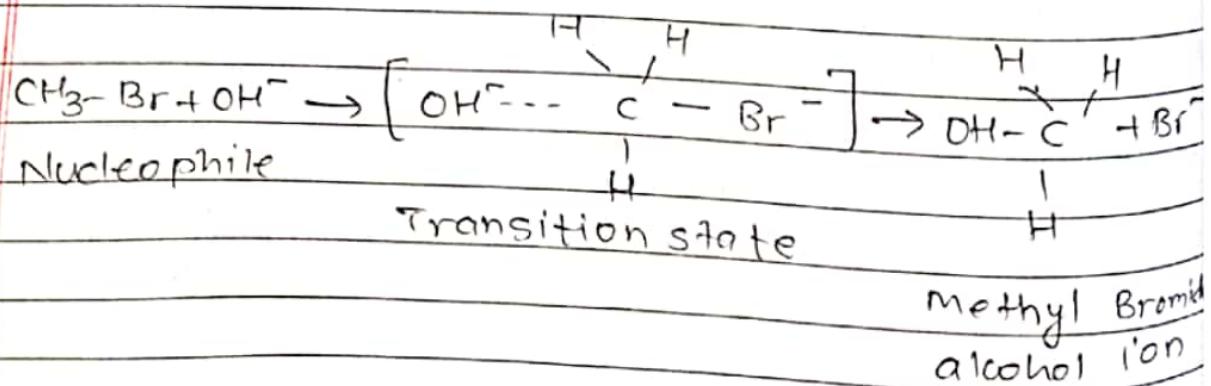
Where, k = Rate constant

The reactivity order of S_N^2 reaction is



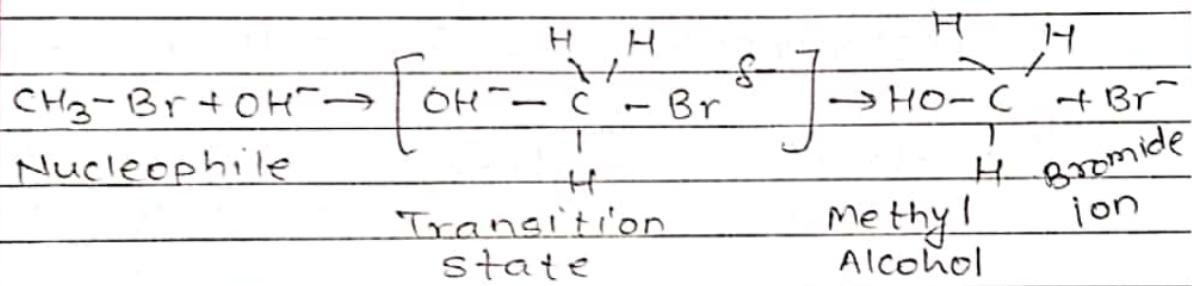
Mechanism of S_{N}^2 Reaction

S_N^2 reaction is completed in single step. In this mechanism the attack of nucleophile and release of halide ion takes place simultaneously in which transition state is formed by partial breakage of bond with halide ion and partial formation of bond with nucleophile.



Stereochemistry of S_N^2 Reaction

In this mechanism, there is back side attack of nucleophile to the substrate from the position of $\pm 80^\circ$ away from the leaving group. In this process no intermediate product is formed, so it is one step process. It proceeds with complete inversion of configuration. There is no racemic mixture is produced. The product obtained is 100% pure. This types of inversion is called Walden inversion.



Difference between $\text{S}^{\text{N}}\text{I}$ and $\text{S}^{\text{N}}\text{2}$ reaction

S_N^2 Reaction	S_N^2 Reaction
1) It is unimolecular process.	1) It is bimolecular process.
2) It follows first order kinetics.	2) It follows second order kinetics.
3) It is completed in two steps.	3) It is completed in single step.

4) It depends on substrate molecule only.	4) It depends on both substrate and nucleophile.
5) Carbocation is formed as the intermediate product.	5) No carbocation is formed during the reaction.
6) Nucleophile attacks from both sides of carbocation	6) Nucleophile attacks from back sides of substrate molecule.
7) Reactivity order of S_N^1 reaction is $(CH_3)_3C-Br > (CH_3)_2CH-Br - CH_3-CH_2- Br$	7) Reactivity order of S_N^2 reaction is $CH_3-Br > CH_3-CH_2-Br > (CH_3)-Br > (CH_3)_2C-Br$
8) It favors polar solvent	8) It favors non-polar solvent.
9) It forms racemic mixture i.e. inversion and retention product.	9) It forms 100% pure product (complete inversion reaction)

Factors Affecting S_N^1 and S_N^2 Reaction

(i) Nature of Nucleophile

S_N^1 reaction depends only on the concentration of substrate and nucleophile is not involved in the rate determining step. Hence, the nature of nucleophile does not affect the

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rate of reaction.

In SN^2 reaction, rate depends upon both the concentration of substrate and nucleophile. Stronger the nucleophile higher is the rate of reaction.

(ii) Nature of Solvent

For SN^1 reaction polarity of solvent is important for the formation of carbocation. Greater is the polarity of solvent, higher is the rate of reaction, but SN^2 reaction favors non-polar solvent because reactants are more polar in transition state. Hence, if polar solvent is used it slows down the rate of reaction. Therefore, non-polar solvent favors SN^2 reaction.

(iii) Nature of Substrate

SN^1 reaction favors tertiary haloalkanes and primary haloalkane favors SN^2 reaction.

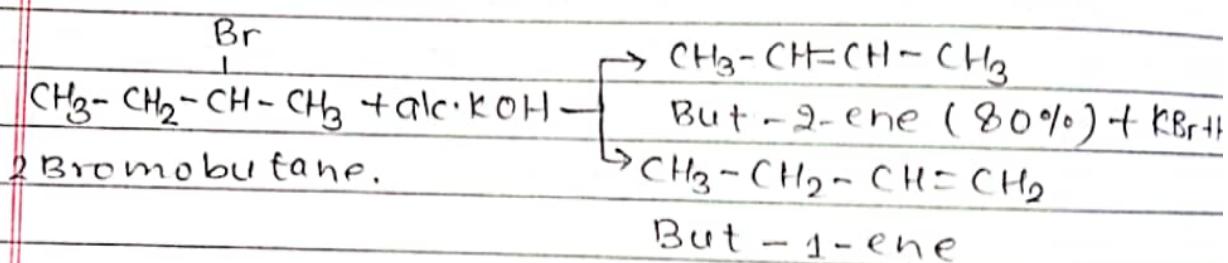
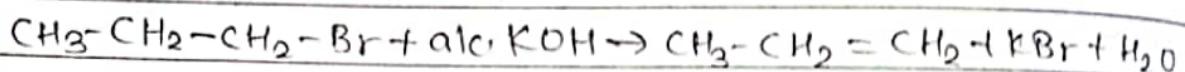
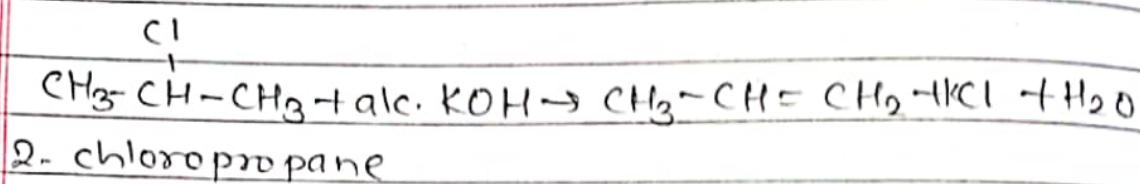
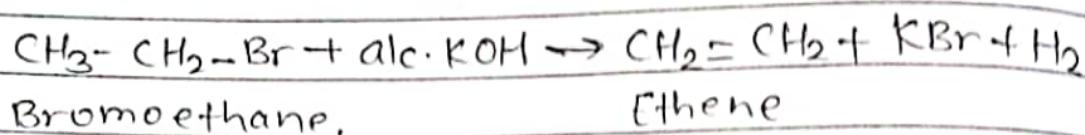
Elimination Reaction

Those organic reaction in which two atom or group of atom attached to the adjacent carbon atom are eliminated from a molecule to form multiple bond is known as elimination reaction (or dehydrohalogenation or β -elimination or 1,2-elimination).

QUESTION

In this reaction, halogen atom is removed from alpha position and hydrogen atom is removed from beta-position.

For eg:



According to Saytzeff rule, highly substituted alkene is the major product.

It states that, "If there is possibility of formation of two or more unsaturated hydrocarbon by elimination reaction, the alkene with higher substitution is the major product."

Types of Elimination Reaction

(e) E^2 Reaction (Unimolecular Elimination Reaction)

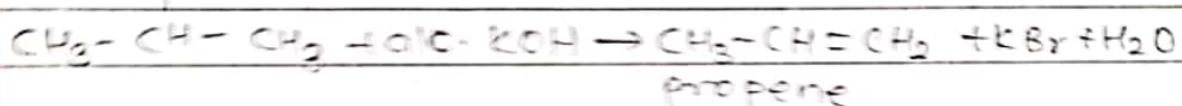
The elimination reaction whose rate depends upon concentration of substrate molecule only is known as E¹ reaction. It follows first order kinetics i.e.

Rate of [substrate]

$$\text{Rate} = k[\text{substrate}]$$

Where, k = rate constant

For eg:



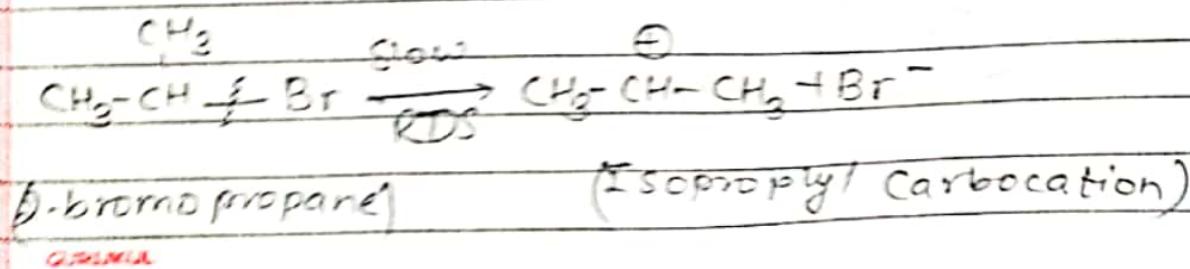
D-bromopropane

Mechanism of Reaction

E^+ reaction is completed in two steps:

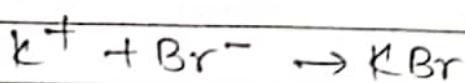
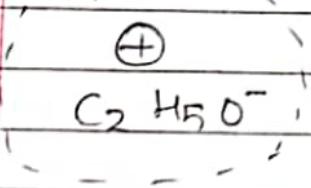
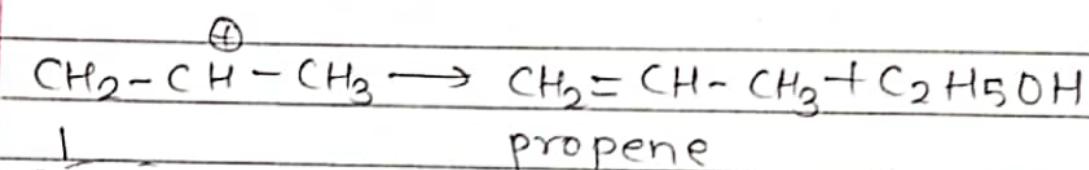
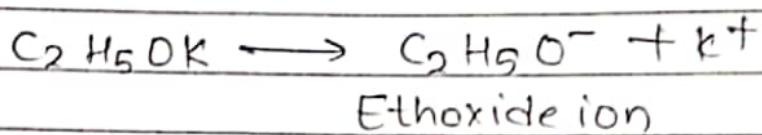
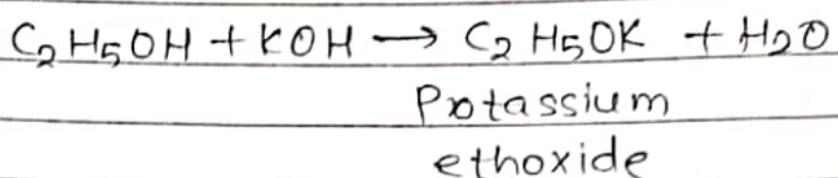
Step 1: Ionization of substrate molecule

In this step, substrate molecule undergoes slow ionization to give carbocation which is rate determining step.



Step 2: Abstraction of β -hydrogen

In this step, β -hydrogen is abstracted by strong base obtained from reagent to give multiple bond between α and β carbon atom.



(ii) E² Reaction (Bimolecular Elimination Reaction)

The elimination reaction whose rate depends upon both the concentration of substrate & reagent is known as E_{2rxn}.

It follows second order kinetics.
i.e.

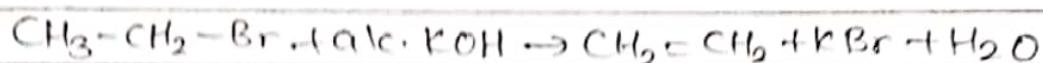
Rate \propto [substrate][Reagent]

$$\text{Rate} = k[\text{substrate}][\text{Reagent}]$$

where,

k = Rate constant.

For eg:



Bromoethane

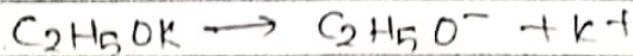
Ethene

Reaction Mechanism

It proceeds through single step, in which β -hydrogen is removed from β -carbon atom and halogen atom is removed from α -carbon atom simultaneously. As a result, multiple bond is formed between carbon-carbon bond in the transition state. Finally, transition state is decomposed to give unsaturated hydrocarbon.

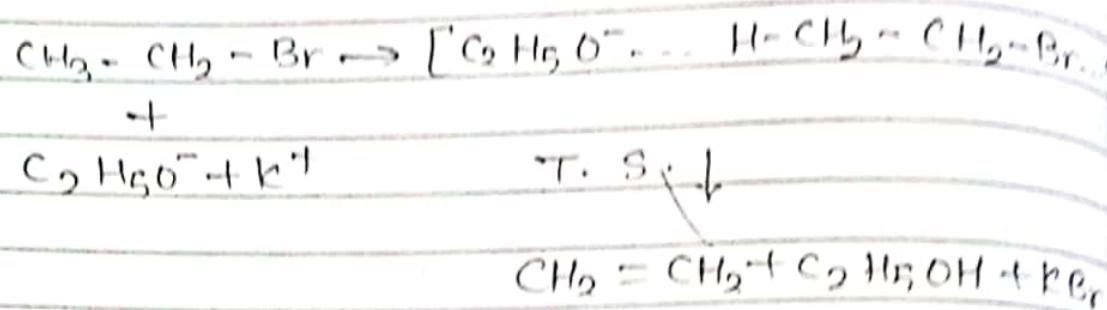


Potassium
ethoxide



Ethoxide
ion

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Reactivity Order

$E^1 \text{ Rxn}$: $3^\circ > 2^\circ > 1^\circ$ Haloalkane

$E^2 \text{ Rxn}$: $1^\circ > 2^\circ > 3^\circ$ Haloalkane.

Factors Affecting E^1 & E^2 Rxn

(i) Nature of Base

Strong base favors E^2 reaction because there is direct abstraction of hydrogen by base and E^1 reaction favors weak base.

(ii) Nature of Solvent

Polar solvent favors E^1 rxn because there is ionization of substrate molecule and E^2 reaction favors non polar solvent.

(iii) Nature of substrate

Tertiary haloalkane favors the E^1 reaction and primary haloalkane favors E^2 reaction.

Assignment1) Difference between E¹ and E² reactionE¹ Reaction

1) E¹ reactions are a type of two-step elimination reactions.

2) E¹ reaction occurs in either the complete absence of bases or in the presence of weak bases.

3) The reaction mechanism of E¹ reactions are known as unimolecular eliminations.

4) E¹ reactions are common in tertiary alkyl halides and some secondary alkyl halides.

5) It's reactivity order is $3^\circ > 2^\circ > 1^\circ$

6) It's rate depends upon concentration of substrate molecule only.

E² Reaction

1) E² reactions are a type of one-step elimination reactions.

2) E² reactions occur in the presence of strong bases.

3) The reaction mechanisms of E² reactions are known as bimolecular eliminations.

4) E² reactions are common in primary alkyl halides and some secondary alkyl halides.

5) It's reactivity order is $1^\circ < 2^\circ < 3^\circ$

6) It's rate depends upon both concentration of substrate and reagent molecule.

7) It favors polar protic solvent.

7) It favors polar aprotic solvent.

8) Its rate law expression is given by:

$$\text{E1: Rate} = k[\text{Substrate}]$$

8) Its rate law expression is given by:

$$\text{Rate} = k[\text{substrate}][\text{Base}]$$

Environmental Chemistry

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Date: / /

Assignment

Ques Define air pollution. Mention its main causes of pollution. Also point out its adverse effect as well as control of air pollution.

Ans:

Air is polluted by addition of poisonous gases like CO, NO, NO₂, SO₂, SO₃, O₃, H₂S dust, smoke and unburnt hydrocarbons like CH₄, C₂H₅, CFC etc. produced by either natural phenomena or human activities. These gases are continuously released to the atmosphere day by day.

Main causes of air pollution:-

- Burning of coal, wood and oils.
- Internal combustion of engines of car, buses, trucks, trains etc.
- Chemical industries: various poisonous gases like CO, NO, NO₂, SO₂, SO₃ etc are released.
- Dust produced from heavy traffic and crowded population.
- Carbon monoxide by incomplete combustion hydrocarbon, fuels etc.

Effects of air pollution:

- Human being suffers from diseases like heart failure, lungs disease, and high blood pressure.
- It increases tension makes fatigued and restless.

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- It may cause blindness, skin disease etc.
- Man may become senseless.

Prevention of the air pollution

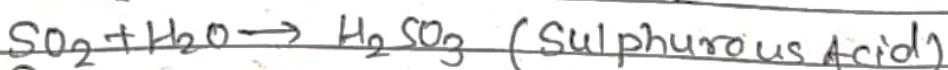
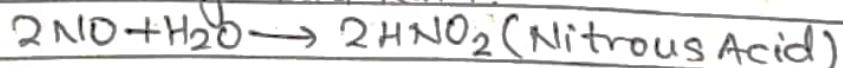
- It can be minimized the production by adding tetra ethylene lead in petrol.
- By planting green trees.
- By using alternative sources of energy instead of fossil fuels.
- By banning the use of low quality gasoline.
- It can be controlled by make awareness to air pollution.

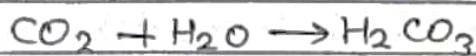
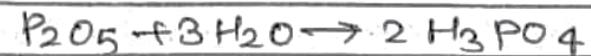
b) Define acid rain. Discuss about the source, effect and important control method of acid rain.

Answer:-

The atmosphere is polluted by different oxides of non metals like CO , CO_2 , NO , NO_2 , Na_2O_5 , SO_2 , P_2O_5 , As_2O_3 etc produced from industries, factories. These non-metallic oxides combine with water in atmosphere to form acids and fall in the form of droplets on earth surface which is called as acid rain.

Sources of Acid Rain :-





Some of the effects of acid rain are:-

- It increases the acidity of soil which becomes unfit for crops production.
- It destroys forests, grassy lands, fertile lands.
- It causes stone leprosy.
- It corrodes metallic materials, pipes.
- Natural beauties like mountains, falls, rivers, coastal areas etc are destroyed.
- It disturbs the terrestrial & arboreal as well as equatorial ecosystems.
- It causes sterility in animals, fishes, birds and retard production vegetations.

Control measures of acid rain

- By applying alternative sources of energy instead of coal and gasoline.
- By banning of use of high fuel consuming vehicles, machines.
- By treating smoke of industries with suitable metals.
- Controlled by planting green trees.

2 (a) What is hard water? Write its types and also method of removal.

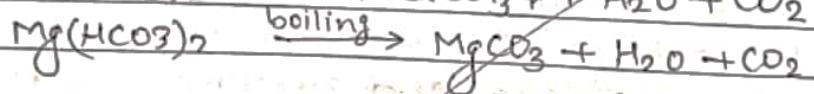
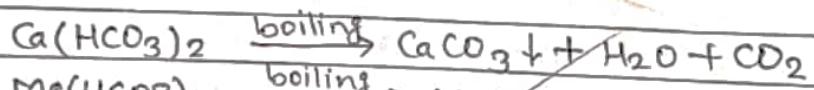
Ans:

The water which gives low or no froth with soap and detergent is known as hard water. It is due to the presence of bicarbonates, sulphates chlorides, nitrates of calcium and magnesium.

There are two types of hardness of water:

1) Temporary Hardness

Temporary hardness of water is due to presence of bicarbonates of calcium and magnesium in the water. It can be easily removed by simply boiling of water. Calcium bicarbonate and magnesium bicarbonates are converted into carbonate forms which settle down.



2) Permanent Hardness

Permanent hardness is due to presence of sulphate, chlorides, nitrates of calcium and magnesium. Such water can't be removed by boiling and advanced methods are applied.

First of all total hardness of water is determined by titrating with EDTA and then permanent hardness is determined by same

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method. Temporary hardness is determined by subtracting amount of permanent hardness from total hardness.

For total hardness:

For determination of total hardness of water a sample of 50ml cold water is titrated with EDTA (Ethylene Diamine Tetra Acetate) by using solo chrome black T prepared in the basic buffer solution till wine red color changes into clear blue color.

2 (b) Define alkalinity. How it is eliminated in laboratory? Describe it.

Ans:-

Alkalinity is the water quality parameter that determines the presence of dissolved hydroxide, carbonates and bicarbonates in the water. These may be present alone or in the mixture form. Alkalinity also causes the hardness of water and increases turbidity of water. Such water can corrode water pipes, boiler and can damage liver, kidney etc.

Alkalinity can be eliminated in laboratory using following steps:-

1. Obtain the water sample with high alkalinity that needs to be treated.

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- 2) Add a suitable acid, such as H_2SO_4 or HCl in limited amounts to neutralize the alkalinity.
- 3) Continuously monitor the pH of the water sample during the acid addition to ensure complete neutralization.
- 4) Stop adding acid when the pH reaches the desired level or when the alkalinity is effectively eliminated.
- 5) After treatment, retest the water sample to confirm the reduction or elimination of alkalinity.

3(a) What is water pollution? Point out the major causes of water pollution, their adverse effect and possible remedies.

Answer:

The state of deviation from the pure condition of water due to mixing of foreign substances whereby its normal functions and properties are affected is known as water pollution.

Major Causes of Water Pollution

(i) Sewage & domestic wastes:

It includes excreta of animals and human, dead and decay parts of animals and plants, sewage, sludge, soap, etc.

(ii) Industrial effluents:

It contains toxic materials, chemicals and hazardous compounds like aldehydes, ketones, phenols, cyanides, oils, grease, dyes, corrosive metals like Pb, Hg, S's etc.

(iii) Agricultural discharges:

The residues of chemical fertilizers, insecticide and herbicides retain on the soil surface and dissolve in water due to which uncontrolled growth of weed occurs and ponds^{lakes} etc.

(iv) Siltation

It is the process of mixing of soil and rock particles into water. It is serious problem for hilly region.

Adverse effect of water pollution

i) Water is carrier of pathogenic micro organism and can cause adverse effect to public health.

The water borne diseases like typhoid, paratyphoid, fever, dysentery, cholera etc.

(ii) Destroy of aquatic ecosystem

Sewage and run off from agricultural lands provides nutrients to the algae, weeds in the bathroom of water sources & increase the over growth of the plants which cover the pond, lake and finally they in to grassy lands.

(iii) Damage of property of water

Pollutants destroy the natural properties of water.

(iv) Drinking Water contamination

Water pollution can render drinking water

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sources, unsafe, requiring expensive treatment or forcing people to rely on alternative, potentially unreliable sources.

Control Measures

- The wastes from industries, factories, pharmaceutical & hospitals must be managed properly.
- Most of wastes must be processed for recycling.
- Sufficient & accessible dumping site must be managed in rural & urban areas.
- Public awareness campaign should be launched.

3(b) Define alkalinity? How it is measured? in laboratory explain.

Answer:

Alkalinity is the measure of water's ability to resist changes in pH and is influenced by the presence of bicarbonate and hydroxide ions.

Alkalinity can be measured in laboratory using following steps:

a. Prepare a representative water sample by ensuring it is properly collected and stored to maintain its integrity.

b. Add a suitable indicator, such as phenolphthalein or bromothymol blue, to the water sample. This indicator will change color at specific pH levels.

c. Use a burette to add a standard acid solution

typically HCl, or H₂SO₄ to the water sample while continuously stirring.

d. The acid reacts with the alkaline components in the water, causing the color of the indicator to change.

e. Continue adding the acid solution until the color changes reaches a specific endpoint. For phenolphthalein, this is often a color change from pink to colorless. For bromothymol blue, it could be a change from blue to yellow.

f. Note the volume of acid solution added from the burette, as this is used to calculate the alkalinity.

g. Repeat the measurement at least two more times to ensure accuracy and obtain an average value.

i. Calculate the alkalinity using appropriate formulae based on the volume of acid solution added and the molar concentration of the acid.

j. Report the alkalinity measurement in the desired units, such as milligrams per litre (mg/l) or parts per million (ppm) of calcium carbonate (CaCO₃) equivalent.

Q. 4 (a) What is soil pollution? Discuss its effect on agriculture and living beings. How can it be controlled?

Answer:

Soil pollution refers to the contamination or degradation of soil by pollutants, including chemicals, heavy metals, pesticides, industrial waste and improper disposal of hazardous substances.

Effects of soil pollution on agriculture & living beings include.

a) Agriculture

- Reduced fertility and nutrients of soil.
- Impaired plant growth and lower crop yields.
- Contamination of food crops with toxic substances.
- Disruption of nutrient cycles of ecosystem functioning.

b) Living Beings

- Health risks from consuming contaminated food.
- Accumulation of toxins in animals and potential transfer through the food chain.
- Negative impacts on soil dwelling organisms and beneficial organisms.

Control Measures of soil pollution:

- It can be controlled by replacing the use of insecticides, fungicides by biological methods of control.

- Soil testing & monitoring.
- By dumping domestic, industrial & chemicals.
- By advising to apply lead free gasoline.
- By recycling the domestic materials.

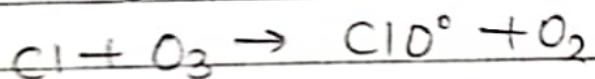
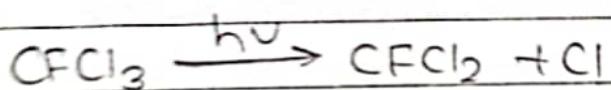
4(b) What is green house effect? Describe the photochemistry of ozone layer depletion.

Answer:

Green House Effect

At the day time temperature of earth is increased and at night temperature goes fall down. But green house gases absorbs those temperature & temperature cannot escape out from the earth which causes the global warming. This phenomena is called green house effect.

The photochemistry of ozone layer depletion



The reaction goes on till the ability of destroying by ClO° ion is ceased.

(a) Q.5 Define ozone layer with its importance. Describe how does it forms and depletes?

Answer

The ozone layer is a protective layer of ozone (O_3) in the earth's stratosphere that shields the planet from harmful UV radiations from the sun, preventing its direct impact on living organisms.

The ozone layer forms through a process called ozone-oxygen cycle. It begins when sunlight breaks apart an oxygen molecule (O_2) resulting in two individual oxygen atoms. These atoms can then combine with other oxygen molecules to form ozone (O_3). The ozone molecules absorb and filter out much of the sun's harmful ultraviolet radiation creating the ozone layer in the Earth's stratosphere.

Ozone layer depletion refers to the gradual reduction in the concentration of ozone molecules in the Earth's atmosphere. This depletion is primarily caused by human-made substances known as ozone-depleting substances (ODs), such as chlorofluorocarbons (CFCs) and halons. When released into the atmosphere, these substances break down ozone molecules, resulting in a thinning of the ozone layers. The depletion of the ozone layer allows more harmful UV radiation from the sun to reach the Earth's surface leading to adverse effects on human health, ecosystem & the environment.

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Q.5(b) What is global warming & climate change. What is the main causes behind the depletion of ozone layer. Explain with necessary examples.

→ Global warming refers to the long term increase in Earth's average surface temperature due to human activities, mainly the emission of greenhouse gases in the atmosphere.

Chemical change refers to the broader impacts & shifts in weather patterns, ecosystem and sea levels resulting from global warming. The main causes of ozone layer depletion are stated and explained as:

a) Chlorofluorocarbons (CFCs)

These were widely used in refrigeration, air conditioning, aerosol propellants, foam-blown agents and in the manufacturing of certain products.

b) Hydrochlorofluoro carbons (HCFs)

HCFs were introduced as alternatives of CFCs but still have ozone depleting potential. They were used in various applications such as air conditioning, foam insulation & fire suppression systems.

c) Halons

They were commonly used in fire extinguisher and fire suppression systems.

d) Methyl Bromide: The pesticide & soil fumigant used in agriculture can contribute to ozone depletion.

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Polymers are the large molecules formed by combination of monomer unit. For eg: PVC, polyethene, Nylon 66, DNA, RNA, cellulose, protein etc.

~~Types of Polymer~~

a. Based on Origin

On the basis of origin, polymers are of two types.

(i) Synthetic Polymer (Artificial Polymer)

The polymer which is synthesized in laboratory or in factory is called synthetic polymer. For eg: PVC, polyethene, Teflon, Decron, Bakelite etc.

(ii) Natural Polymer

The polymer which are obtained from nature is called natural polymer. For eg: Cellulose, DNA, RNA, protein etc.

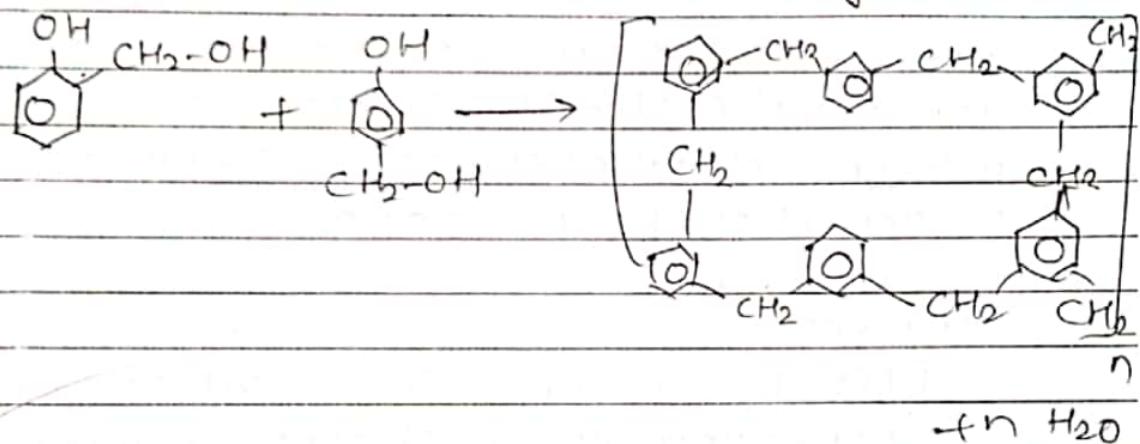
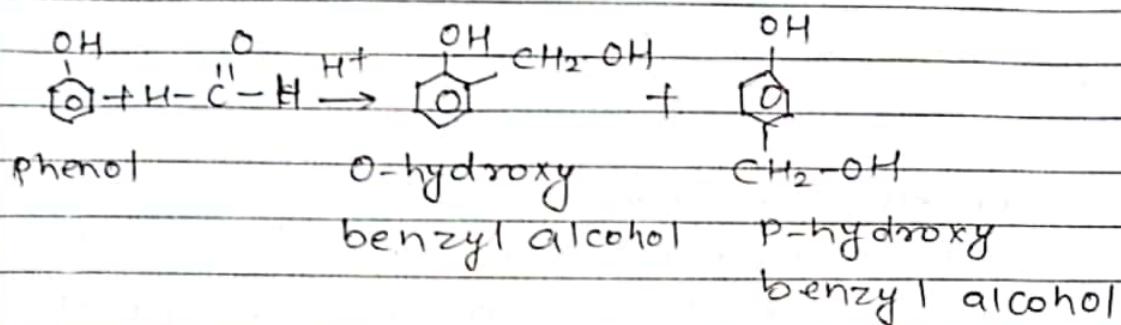
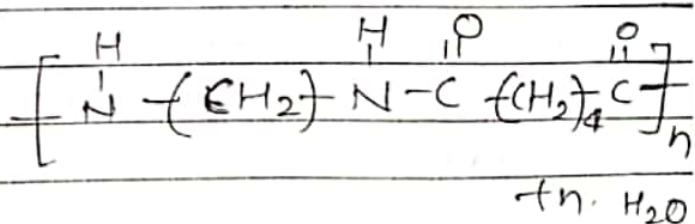
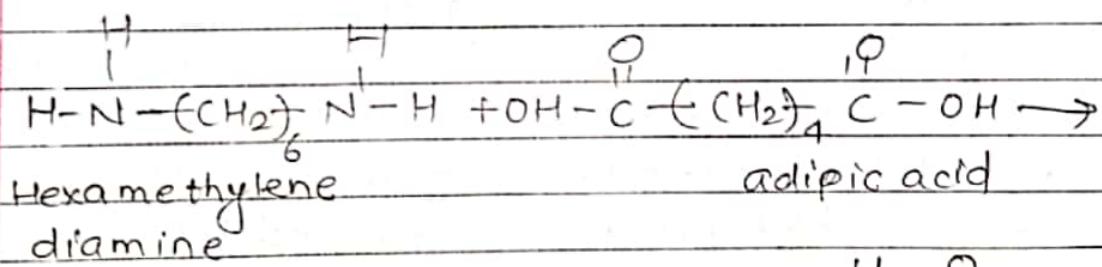
b. Based on Monomer Unit

(i) Homo polymer

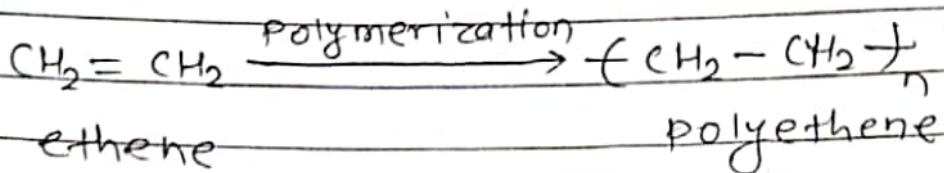
The polymer which contains same monomer unit is called homo polymer. For eg: PVC, Teflon, Polyethene, Polystyrene etc.

(ii) Copolymer

The polymer which contains different monomer unit is called copolymer. For eg: Bakelite, Dacron, Nylon 66.

BakeliteNylon 66Addition Polymer

The polymer which is formed by the repeated addition of monomer molecule having at least one multiple bond is known as addition polymer and the phenomenon is called addition polymerization. *(Curious)*



Condensation Polymerization

The polymer which is formed by the combination of monomer unit having atleast two functional group. With the elimination of small molecule like HCl, H₂O, NH₃ etc is known as condensation polymer and the phenomenon is known as condensation polymerization.

Difference

Addition Polymerization	Condensation Polymerization
a) Monomer unit contains atleast one multiple bond.	a) Monomer unit contains atleast two functional group.
b) Small molecule like HCl, H ₂ O, NH ₃ are not removed by bi-product.	b) Small molecule like HCl, H ₂ O, NH ₃ are removed by bi-product.
c) It gives usually thermo plastic.	c) It gives usually thermo setting plastic.
d) The polymer formed is soft.	d) The polymer formed is hard.
e) It gives linear chain polymer.	e) It gives three dimensional polymer.

f) It can be easily mould.

g) For eg: PVC, Teflon etc.

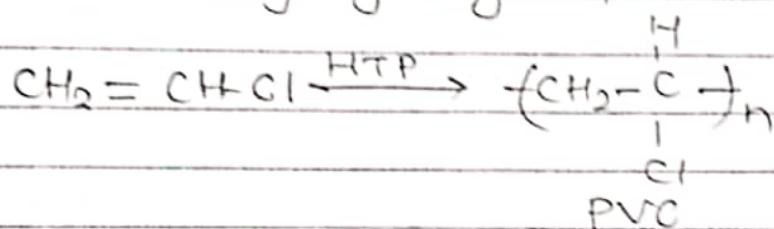
f) It cannot be easily mould.

g) For eg: Nylon 66, Bakelite etc.

Preparation, Properties and Uses of Some Polymer

1) Polyvinyl chloride - pvc

It is the homopolymer of vinyl chloride. It is prepared by polymerization of vinyl chloride under high temperature and pressure in presence of hydrogen peroxide (H_2O_2).



⇒ Properties

- ↳ It is colorless, odourless, and non-inflammable.
- ↳ It is hard and rigid.
- ↳ It is not recommended for use above $70^{\circ}C$.
- ↳ It is attacked by many organic solvent like Ketone, Carbonyl Sulphide (CS_2) but resistant towards oil.

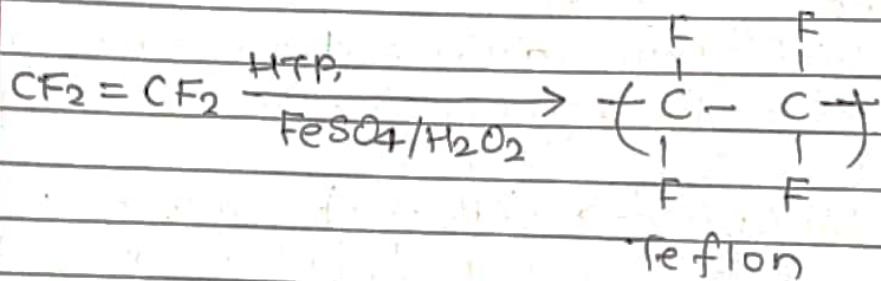
⇒ Uses

- ↳ It is used for making PVC pipe.
- ↳ It is used in the manufacture of raincoat Insulator.
- ↳ It is used for making tyres of cycle & motorcycle.

- ↳ It is used in the manufacture of carpet, table cloth & covering etc.
- ↳ It is used for making hand bag, toy, curtains.

2) Teflon

It is the homopolymer of tetrafluoro ethene ($\text{CF}_2 = \text{CF}_2$). It is prepared by heating tetra fluoro ethene under high temperature and pressure in presence of $\text{FeSO}_4 / \text{H}_2\text{O}_2$.



⇒ Properties

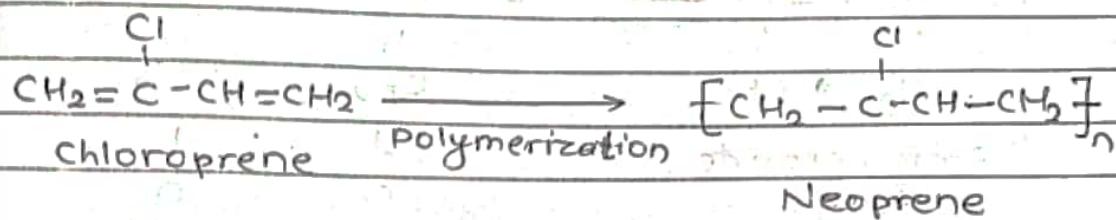
- ↳ It is hard, very strong, tough material.
- ↳ It is resistance towards heat.
- ↳ It is incombustible up to 300°C .

⇒ Uses

- ↳ It is used for making non-sticky pan.
- ↳ It is used for making electrical insulator in motor, transformer, cable & other electrical equipment.
- ↳ It is used in the manufacture of artificial limb.

3) Neoprene

It's a synthetic rubber. It was first time invented in 1931. It was by the Polymerization of chloroprene.



(2-chloro-but 1,3-diene)

⇒ Properties

- ↳ It is a synthetic rubber.
- ↳ It is non-toxic.
- ↳ It has high tensile strength (elasticity)
- ↳ It is resistant towards heat.
- ↳ It does not undergo oxidative degradation.

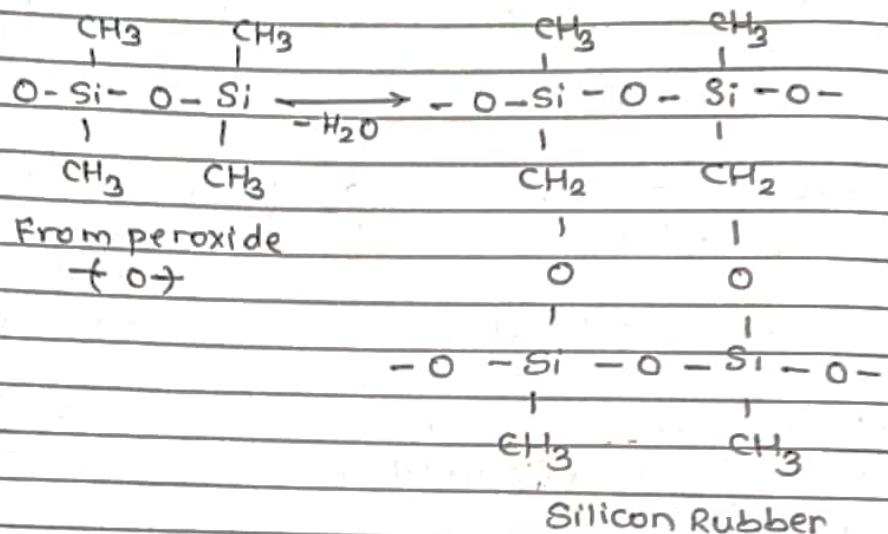
⇒ Uses

- ↳ It is used in athletic equipment such as gloves, shoes, hats, etc.
- ↳ It is used in boot cushions.
- ↳ It is used for making shoe soles.
- ↳ It is used in wire & cable insulation.
- ↳ It is used for engineering purposes.

a) Silicon Rubber (Neil-Armstrong Boot)

Silicons are polymer having high thermal stability. So, they are called high temperature polymer. They are obtained by mixing high molecular weight of linear dimethyl silicon.

Polymer with fillers like silica, carbon black and peroxide.



→ Properties

- ↳ They have low chemical reactivity.
- ↳ They are less toxic and does not support micro biological growth and can repel water.
- ↳ They have high range of thermal stability.
- ↳ It is excellent resistant towards oxygen, ozone and UV-light which are widely used in construction industry for fire protection, coating.

→ Uses

- ↳ They are used in the manufacture of tyres of fighter aircraft.
- ↳ They are used for making lubricants, paints & protective coating for fabrics.
- ↳ They are used for making boots for use at very low temperature. (Neil Armstrong used Silicon rubber boot when he walked in the Moon)

- They are used for making insulating for washing machine & electronic blankets.

5) Biodegradable Polymer

Those polymer which are decomposed in natural aerobic and an aerobic environment are called biodegradable polymer. For eg: cellulose, starch, poly caprolactone, collagen, polypeptides etc.

(i) Natural Produced Polymer:

Poly hydroxy alcanoate, poly acetic acid.

(ii) Synthetic Polymer

Poly butylene succinate, poly caprolactone, cellulose acetate & Nitro cellulose.

⇒ Application

- They are used in agricultural field for making composed fertilizer.
- They are used in biomedical application.
- They are used in waste manage system.

Note: Biodegradable refers to organic material that can be easily decomposed by leaving organism.

6) Non-Biodegradable Polymer

The polymer which do not undergo decomposition due to expose of oxygen, moisture, Ozone, heat, radiation or micro or organism is known as non-biodegradable polymer.

micro

They are not decomposed by other organisms or other biological factor. Most of the synthetic polymers are non-biodegradable polymer. For eg: polyethylene, Teflon, Nylon, PVC, Dacron.

⇒ Application

7) Conducting Polymer

The organic polymer which conduct electricity is known as conducting polymer. They have alternate single and double bond along with polymer backbone. For eg: polyaniline, polyacetylene, poly pyrrole. They are mainly classified in following type:

a. Intrinsically Conducting Polymer (ICP)

It consists of delocalized π -electron system. For eg: polyaniline, polyacetylene, poly pyrrole. They are further classified in:-

(i) Doped Conducting Polymer (DCP)

They are obtained by exposing a polymer with a charge agent in gas phase or in solution phase.

⇒ i-doping

They are treated with Lewis Acid. For eg: PF_6^- (Hexa Fluoride Phosphorous), Iodine ($I_2\text{Br}_2$), AsF_5 (Arsenic Penta Fluoride).

→ N-doping

They are treated with Lewis base. For eg:
Lithium, Calcium, Sodium.

b. Extrinsically Conducting Polymer (ECP)

They are externally added with polymer. They
are of following types:

(i) Conductive Element Filled Polymer

They are added with carbon black, metallic
fibres.

(ii) Blended Conducting Polymer

They are obtained by mixing with another
substance and change their physical and
chemical appearance.

→ Application

They are used in the manufacture of chemical
sensor.

→ They are used for manufacture of PCB (Printed
Circuit Board) because it protect the copper from
corrosion and prevent its solder ability.

→ They are used in LED, LASER & Transistor.

→ They are used for micro wave absorbant.

8) Non-Conducting Polymer

The polymer that are electrically insulating materials are known as non-conducting polymer. These materials are mainly thermo plastic and thermo setting polymer. They cannot conduct electricity through itself. We can use non-conducting materials for a complete range of mechanical, electrical & thermal properties.

Transition Metal & Their Applications

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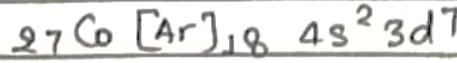
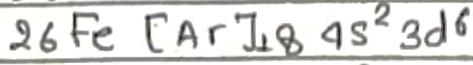
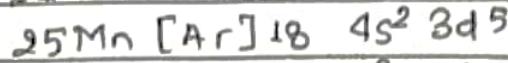
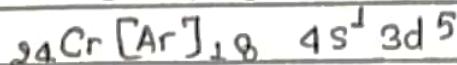
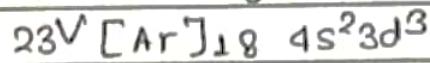
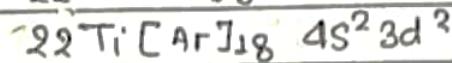
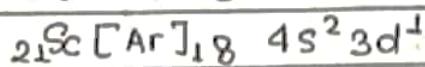
The elements of III B, IV B, V B, VI B, VII B, VIII, IB and IIB of the periodic table are called transition elements. There are four transition series starting from 3d, 4d, 5d and 6d series. The first transition series consists of 10 elements starting from Scandium (Sc-21) to Zinc (Zn-30).

The second transition series consists of 10 elements starting from Ytterium (Yt-30) to Cadmium (Cd-48).

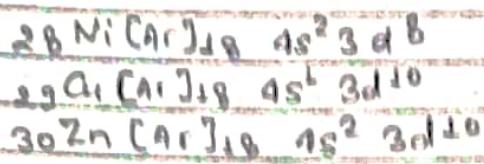
The third transition series consists of 10 elements starting from Lanthanum (57) to Hafnium (72) and fourth transition series is incomplete. It contains elements Actinium to Copperium.

Electronic Configuration

The general electronic configuration of transition element is $ns^{1-2}(n-1)d^{1-10}$. Both half filled and completely filled orbitals are more stable than other orbitals.



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Note: Cu & Zn are not taken as true transition element because of their completely filled d-orbitals.

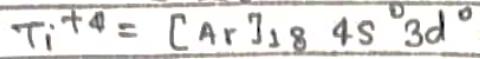
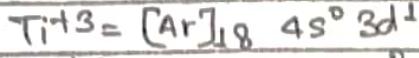
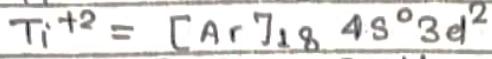
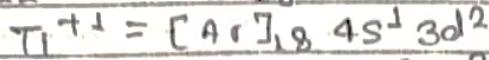
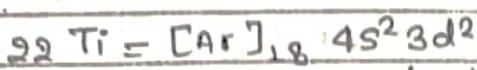
Variable Oxidation State

Most of the transition element shows variable oxidation state due to participation of ns-orbital and $(n-1)d$ orbital. Ti shows +1, +2, +3 and +4 oxidation no.

The variable oxidation state is shown due to following two points:

- (i) Lowest oxidation number is equal to no. of e^- present in ns-orbital.
- (ii) Highest oxidation number is equal to sum of number of electron present in ns-orbital and $(n-1)d$ -orbital.

For eg:



Magnetic Property

Most of the transition elements are paramagnetic in nature. The transition element (metal) or complex whose central metal ion contains

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one or more unpaired electron are paramagnetic in nature. While those central metal or complex compound do not contain unpaired electron are diamagnetic in nature. Paramagnetism arises due to spinning of unpaired electron on its own axis which creates magnetic moment called spin moment. The magnetic moment of unpaired electron is given by spin only formula. i.e.

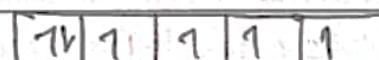
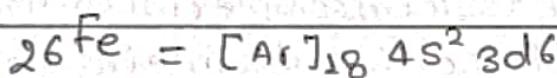
$$\mu = \sqrt{n(n+2)} \text{ B.M}$$

Where,

n = no. of unpaired electron

B.M. = Bohr magneton

For e.g:



$$n = 4$$

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

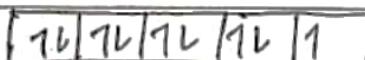
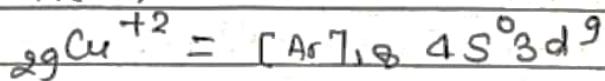
$$= \sqrt{4(4+2)} \text{ B.M}$$

$$\therefore \mu = 4.89 \text{ B.M}$$

Q. Cu^{+2} are paramagnetic in nature while Zn^{+2} are diamagnetic in nature. Why?

Sol:-

Here,



QUESTION

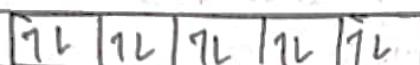
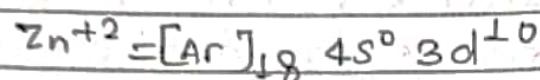
$$n = \pm$$

'Cu' contains 1-unpaired electron

$$\mu = \sqrt{n(n+2)} \text{ BM}$$

$$= \sqrt{1(1+2)}$$

$$\therefore \mu = \sqrt{3}$$



$$n=0$$

$$\therefore \mu = \sqrt{0(0+2)}$$

$$\therefore \mu = 0$$

Complex Formation

Transition metal atom or cation derived from them have an ability to form complex with ligand (CN, H₂O, NH₃ etc). These ligand contains one or more lone pair of electron which can easily donate to the transition metal to complete vacant d-orbital by forming ligand to metal bond (L-M).

a) Transition metal forms complex compound due to following reason. The transition metal or cation have vacant d-orbital. They can accommodate lone pair of e⁻ donated by ligand.

b) Due to small size transition metal or cation & high effective nuclear charge. They have high +ve charge density which makes attraction of ligand towards metal atom or cation.

Atomic Radii

Elements	Sc	Ti	Vn	Cr*	Mn	Fe	Co	Ni	Cu*	Zn
At. radius	1.44	1.32	1.22	1.17	1.17	1.16	1.16	1.15	1.17	1.15

The atomic radii decreases with increase in atomic number. This is due to increase in nuclear charge which pulls electron inward as a result decrease in volume. The atomic radii of the element from chromium to copper are very close to one another, this is due to increase in atomic no. and increase in nuclear charge. So, the attraction towards $4s^2 e^-$ is enhanced. The atomic radii increases all moving down the group. This is due to addition of new shell in each step.

Color Formation

The color of transition metal or complex ion can be studied into following two points.

1) Color of Complex Ion whose central metal contains partially filled or half filled d-orbitals:

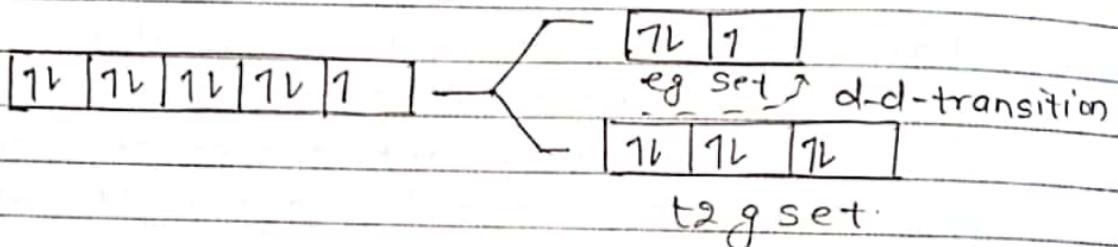
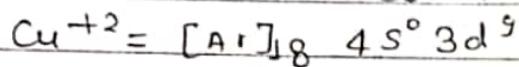
The transition metal whose central metal ions contain partially filled or half filled d-orbitals are colored in solid or solution form.

According to (Crystal Field Theory) CFT, the five d-orbital (d_{xy} , d_{yz} , d_{zx} , $d_{x^2-y^2}$ & d_{z^2}) have equivalent energy. When white light falls on these compounds five d-orbitals are splitted into two set i.e. t_{2g} (triply degenerate) and e_g (doubly degenerate). t_{2g} set contains

dxy , dyz & dzx and eg set contains dx^2y^2 & dz^2 .

The orbitals in which d-d transition occurs are colored in their solution or solid form. For e.g.: Cu^{+2} ion is blue in colour.

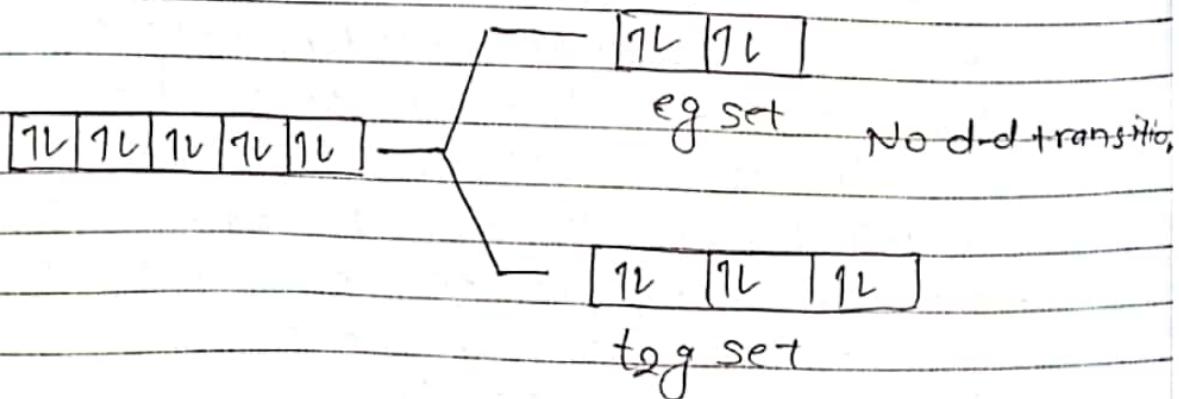
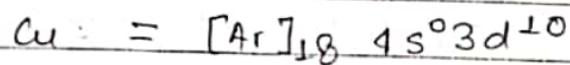
Cu^{+2} ion is blue in color.



2) Color of the complex ion whose central atom contains empty or completely filled d-orbitals are colorless

This is because d-orbital of central atom or ion do not contain any electron or completely filled d-orbital have no any possible dd transition. Hence no light of any color is absorbed by such ion.
For eg:

Cu^{+1} is colorless in solid or solution form



Catalytic Properties

Transition metal forms catalyst. The main reason for catalytic properties is due to formation of complex compound and variable oxydation number.

Catalyst	Uses
Fe/Mo	Production of ammonia NH_3 in Haber's process.
Ni/Pt	Hydrogenation process
V_2O_5	Production of SO_3
Pd/ BaSO_4	Rosenmund Reduction

Application of 3d-Series Element

1) Scandium (Sc)

→ Scandium has great tendency to form complex compound. For eg $[\text{Sc F}_4]^{++}$, $[\text{Sc F}_5]^{+1+}$ etc.

2) Titanium (Ti)

→ It is used in high speed aircraft and chemical industry because it has low thermal expansion, corrosion resistance and lightness.

→ Ti is also used in photometric cell.

→ Alloy of Ti with chromium iron and Molybdenum (Mo) are used for making gears and propellers.

3) Vanadium (V)

Oxides of vanadium (V_2O_5) is used for manufacture of H_2SO_4 .

Curriculum

4) Chromium (Cr)

→ It is used for making stainless steel.

5) Cobalt (Co)

→ The compounds of Co is used in the preparation of green paint.

→ It is used in the preparation of Vitamin-B₁₂.

6) Nickel (Ni)

→ It is used in the hydrogenation process and reducing agent.

7) Copper (Cu)

→ It is used in the manufacture of red paint.

→ It is used to make electrical wire.

8) Zinc (Zn)

→ It is used in the white vitrol

→ It is used in the preparation of Lithopone.
(BaS-ZnSO₄)

→ It is used in the preparation of Calamine (ZnCO₃)

9) Iron (Fe)

→ It is used in making industrial machinery.

→ Used in construction of buildings.

→ Used in making irons.

→ Iron is a trace element that is required for life.

Paint

It is a viscous fluid medium of finely divided pigment which on drying gives impermeable layer. It is used to protect, decorate and adding color to an object.

Characteristics of Paint

- 1) It should have high covering power.
- 2) The layer of paint should not crack on drying.
- 3) It should be weather resistant.
- 4) The layer of paint should be stable.
- 5) Its layer should be highly glossy.
- 6) It should form impermeable layer, uniform layer and effective for corrosion.
- 7) It should be highly adhesive material.

Constituents of Paint

1) Pigment

The important property of a pigment in a paint are colourising powder that is natural and synthetic pigment. Natural pigments are calcium carbonate and mica. Synthetic pigments are copper sulphate, zinc sulphate, ZnSO_4 , CuSO_4 , ZnO , CuO , Cu_2O etc.

2) Medium

The main function of medium is to hold pigment on surface of wall. For eg: Soyabean oil, fish oil, petroleum oil.

3) Thinner

Thinner are added to the paint for decreasing viscosity. For eg: Acetone, terpentine oil, ethyl alcohol, kerosene oil.

4) Drier

The substance which is added to paint for drying purpose are known as drier. For eg: Napthol (Camphor) (નાપ્થોલ)

5) Extender

These are the materials which improve the property of paint. For eg: Silica (SiO_2).

6) Plasticizer

They are used sometime in a paint to keep elasticity to the layer. For eg: Triphenyl phosphat, Tributyl phosphate etc.

Types of paint

1) Varnish

It is the homogenous dispersion solution of natural or synthetic resin. It is used as a decorating & protecting for the surface to produce glossy, lusture & hard appearance.

2) Emulsion Paint

These are dispersion of synthetic resin in water. It contains pigments, medium, extender, preservatives and anti foaming agent. The advantage of emulsion paint is, it was washable.

easily dry and easily diluted with water.

3) Fire resistant paint

It contains binder which breakdown at activated temperature by producing non inflammable gas like carbondioxide gas, ammonia etc. These paint contains PVC and chlorinated rubber.

4) Special Paint

They are various in nature like heat resistant paint which contains metallic powder like aluminium, zinc, Sn and graphite which can withstand temperature up to red hot. They are used in aircraft, oven, & smoted structure.

5) Distemper (Water paint)

The ingredients of distemper are chalk powder, glue, coloring pigment and water. They are used as finishing coat on white washed surface of interior walls.

6) Cement Paints

The ingredients are white cement, limewater and they are widely used in interior and exterior coating of the brick wall.

7) Aluminium Paint

The fine powder of aluminium is mixed with either with sprit(100% alcohol) & oil. It is used to metal surface, widely

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Application of Paint

- (i) To coat the metallic surface for the prevention of corrosion.
- (ii) To make the furniture attractive in appearance.
- (iii) To protect as well as decorate the building.
- (iv) To reduce the foul smelling in ships due to marine worms and fungus attack.

Cement

Cement is a constructive material used for making building, road, temple, bridge, house, etc. First time cement was introduced by Joseph Aspdit in 1924 in England. It is mainly composed of lime, clay and gypsum.

Composition of Cement

Different industry used different oxides in various proportion. Among them portland has following composition:

- i) Lime (CaO) \rightarrow 50-60% चूलडाल
- ii) Silica (SiO_2) \rightarrow 20-25%
- iii) Alumina (Al_2O_3) \rightarrow 5-10%
- iv) Magnesia (MgO) \rightarrow 2-3%
- v) Ferric oxide (Fe_2O_3) \rightarrow 1-2%
- vi) $\text{SO}_3 \rightarrow$ 1-2%
- vii) $\text{Na}_2\text{O} \rightarrow$ 1%
- viii) $\text{K}_2\text{O} \rightarrow$ 1%

Various steps used in the manufacture of cement

1) Crushing and Pulverization

The big lumps of lime stones are crushed into small pieces with the help of Jaw crusher or hammer and made into fine powder with the help of ball mill or stamp mill. This whole process is known as crushing and pulverization.

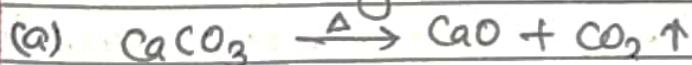
2) Preparation of Slurry of raw materials

In this step the piles of lime are mixed with clay in the proportion 3:1 then 40% water is added to make homogeneous slurry.

3) Calcination

Thus, obtained slurry from above process is introduced into rotatory kiln, with the help of hopper. The rotatory kiln consists of long cylindrical 8-10 ft. in diameter and 100-200 ft. in length. It is heated up to 500°C .

→ The following reaction takes place



(b) Reaction of lime with silica to form di-calcium silicate



(c) Reaction of excess CaO with dicalcium silicate to form tri-calcium silicate.

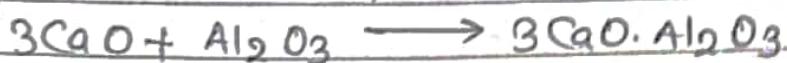


1 pound = 453. gm \Rightarrow 150 billion grains

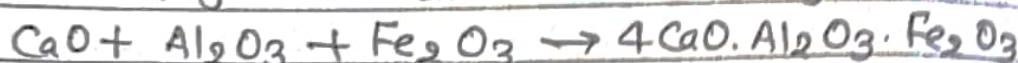
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(d) Reaction of CaO lime with alumina (Al_2O_3) to form tricalcium aluminate



(e) Reaction of lime with alumina and ferric oxide

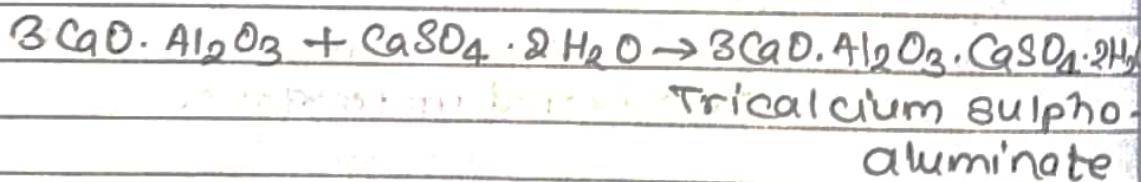


Tetracalcium aluminate
Ferrite

Thus, the resulting mixture is cooled to get clinker.

4) Addition of gypsum

The clinker is cooled and taken out from rotatory kiln then it is mixed with 2-3 % of its weight with gypsum salt. Gypsum salt react with tricalcium aluminate to give crystals of tricalcium sulphoaluminate



5) Final Grinding process

In this process, rotating drums are fitted with steel balls. It is then ground into fine powder that each pound of cement contains 150 billion grains. This is the final product of cement.

6) Packing & Shipping

Finally, manufactured cement is weight out and packed into sack bags or bags and ready

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for selling.

Types of Cement

1) Ordinary Portland Cement (OPC)

The most widely used cement which is used for all general concrete construction is called OPC cement. It is also called basic portland cement. It is categorized into three grades i.e. 33 grade, 43 grade & 53 grade

→ characteristics of OPC cement

- a) It has fast setting property
- b) It uses synthetic material that makes less echo friendly.
- c) It is more expensive than PPC.
- d) It is not favourable in aggressive weather.
- e) The hydration process is very fast as a result high heat of hydration. Therefore, it is unsuitable for mass concreting.
- f) It contains high percentage of chloride sulphate & alkali which makes concrete less durable.

2) Portland Pozzolana Cement (PPC)

PPC is produced by adding pozzolana material like Fly ash and volcanic ash.

→ characteristics of PPC

- It uses natural and industrial waste which makes pollution free environment.
- It is cheaper.
- It has low setting strength initially but

CONTINUE

hardens over periods of time.

→ It is favourable in aggressive environment.

→ The hydration process is slow resulting low heat of hydration. Therefore, it's suitable for mass concreting.

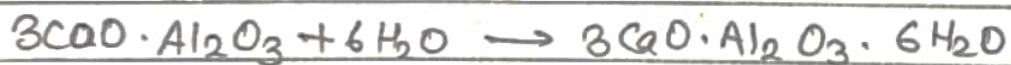
→ It contains lower percentage of chloride, sulphate & alkali which makes concrete more durable.

⇒ Setting of Cement

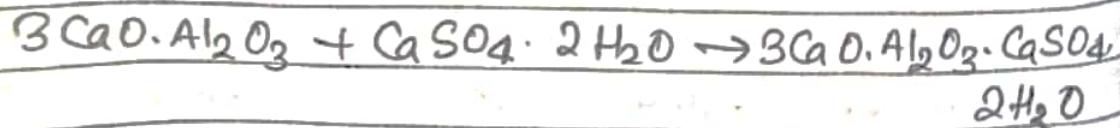
The phenomenon of hardening of colloidal paste of cement into hard mass and resistance for pressure by allowing it to stand with water for certain period is known as setting of cement.

⇒ Reaction in first 24 hours

When water is added to cement, tricalcium aluminate absorbs six molecule of water to form hydrated colloidal gel.

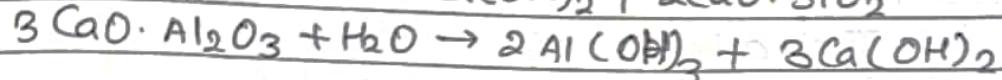
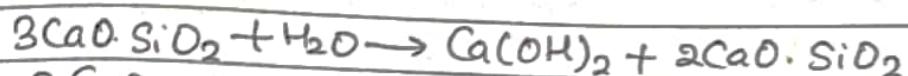


Tricalcium aluminate is fast setting which react with gypsum to form crystals of tricalcium sulpho aluminate



⇒ Reaction within 1 week

Within 7 days period, tricalcium silicate and tricalcium aluminate get hydrolyzed with water to give calcium hydroxide and aluminium hydroxide.



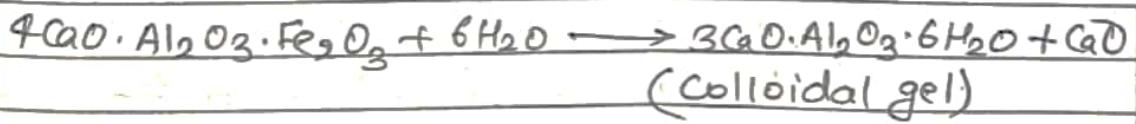
Calcium hydroxide changes into needle shape crystal which get slowly decorated and aluminium hydroxide fills gap resulting into hard mass.

⇒ Reaction between 7 to 28 days

In this period, dicalcium silicate gets hydrolyzed to give colloidal gel.



Finally, the ^{tetra}tricalcium aluminate hydroxide also get hydrolyzed to form colloidal gel.



The gel formed above starts to loose water partially by evaporation. In this way cement sets for construction work.

Photovoltaic (Solar) Cell

A device which converts solar energy into electrical energy is called solar cell or photovoltaic cell.

Principle:

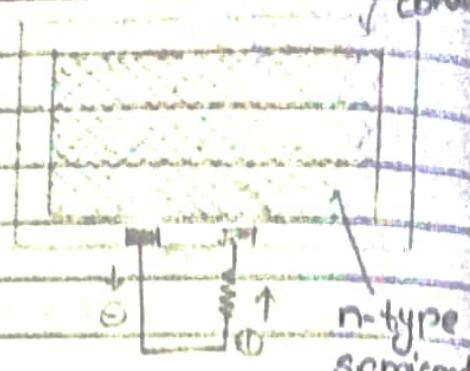
The basic principle involved in the solar cell is based on the photovoltaic effect. When sun rays falls on the two layers of semiconductor devices potential difference between two layer is produced. The potential difference causes flow of electron and produces electricity.
For eg: Silicon Solar cell

Construction:

Solar cell consists of P-type (Silicon doped with Boron) and N-type (Silicon doped with phosphorus) they are enclosed contact to with each other. When the solar rays falls on top layer of P-type semiconductor, the electrons from the valence band get promoted to the conductive band and cross the PN-junction into N-type semiconductor. Thus, potential difference between two layer is created which causes flow of electrons, i.e. electric current.

Thus, when this P&N layers are connected to an external circuit, electrons flow from N-layer to P-layer. Hence, electric current

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is generated.

⇒ Applications

- Solar cells are used in street light.
- Solar cells are used in remote places & in the forest to get electrical energy.
- They are used for eco-friendly driving vehicles.
- They are used in calculator, watch, TV, torch etc.
- Solar cell are used in spacecraft & satellite.

Sensor

A sensor is a device that detect event or changes in quantities & provides corresponding output.

The output is usually electrical or optical signal. For eg: Mercury thermometer convert the measured temperature into expansion and contraction of a liquid which can be visualized in the calibrated glass tube.

A thermocouple convert temperature to an output voltage.

⇒ Types of Sensor

i) Physical Sensor

A physical sensor is a device that provides information about physical property of the system.
For eg: pressure sensor, temperature sensor.

2) Chemical Sensor

A chemical sensor is a device that transforms chemical information ranging from the concentration of a specific sample component to total composition analysis. For eg: Methane, COD (Chemical Oxygen Demand), Ions etc.

3) Potentiometric Sensor.

A potentiometric sensor is a types of chemical sensor that is used to determine the analytical concentration by using electrode.

4) Gas Sensor

Gas sensor is a device which detect the presence of various gases within the area used as a part of safety system. This types of equipment is used to detect gas leak. A Gas sensor can use sound alarm to operate in the area where the leak is occurring. For eg CO_2 , SO_2 , NH_3 , HCN , H_2S , Ag_2S , HF etc.

→ Application of Sensor

→ They are used in following ways:

→ Flame safety

→ Fire detection

→ Alcohol breath test (Breath Analyzer)

→ Environmental monitoring

→ Home safety

→ Detection of harmful gases in mines.

→ Post Anesthesia Care Unit.

National Academy of Science and Technology

(Affiliated to Pokhara University)

Accredited by University Grants Commission (UGC), Nepal 2022

Dhangadhi, Kailali

First Terminal Examination

Level: Bachelor

Semester I, Fall

Year : 2022

Program: B.E. Civil

F.M. : 100

Course: Applied Chemistry

P.M. : 45

Time : 3 Hrs.

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt all the questions.

1. a) Define Electrode potential. How can you determine emf of Zn-Cu Cell ?
Calculate the emf of cell at 25°C. $Zn/Zn^{2+}(0.1M)/Cu^{2+}(0.05M)/Cu$.
Given $E^\circ Zn^{2+}/Zn = -0.76V$ and $E^\circ Cu^{2+}/Cu = +0.34V$. 18
b) Explain the principle, working of lead acid battery. 17
2. a) Define transition elements. What are the application of transition elements in various engineering fields? 17
b) Give reason 18
i) Transition metals and their compounds show paramagnetic behavior.
ii) Zinc (II) compounds are white and diamagnetic.
iii) Transition elements shows complex compounds
iv) Transition elements shows variable oxidation states. $\text{H}_3-\text{CH}-\text{CH}_2$
3. a) Define $S\text{N}^2$ reaction with mechanism and stereochemistry. 18
b) Describe the E^1 reaction with mechanism. 17
4. a) Write the preparation, properties and uses of PVC and Teflon 17
b) What are conducting and non-conducting polymer. Also write their applications. 17
5. a) Define cement. Describe about manufacture of cement in different steps. 17
b) Define explosive substance. How TNT and TNG are prepared. Write their application. 17



POKHARA UNIVERSITY

Level: Bachelor

Semester: Fall

Year : 2022

Programme: BE

Full Marks: 100

Course: Applied Chemistry

Pass Marks: 45

Time : 3 hrs.

Candidates are required to give their answers in their own words as far as practicable.

The figures in the margin indicate full marks.

Attempt all the questions.

1. a) What is Daniell cell? Calculate the emf of given cell

(2) $\text{Sn/Sn}^{2+} (0.2\text{M})/\text{Ag}^+ (0.1\text{M})/\text{Ag}$, where, $E^\circ_{\text{Sn/Sn}^{2+}} = +0.14\text{V}$ and $\text{Ag}/\text{Ag}^+ = -0.8\text{V}$

OR

What is electrochemical series? Calculate the emf of cell at 20°C obtained from the following electrodes

i) $\text{Fe} = \text{Fe}^{2+} + 2e, E^\circ = +0.44\text{V}$

ii) $\text{Cu} = \text{Cu}^{2+} + 2e, E^\circ = -0.34\text{V}$

(b) Explain about the electrochemical mechanism of corrosion.

2. (3) a) What is water pollution? Explain about the sources, impacts and suitable remedies of water pollution.

OR

Give a short account of soil pollution, its sources and impacts.

- b) How can you determine free chlorine present in water in your lab?

3. (6) a) Why all d-block elements are not true transition elements? Give the reasons for following

i) Zn

ii) salts are always colorless

iii) Transition elements represent variable oxidation states.

- (b) Why the transition elements are preferred to produce compounds? Give the applications of transition metals in your field of engineering.

4. (7) a) How does $\text{S}_{\text{N}2}$ reactions differ from $\text{S}_{\text{N}1}$ reaction? Explain with their mechanism taking suitable examples.