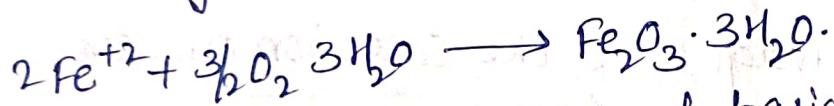


CORROSION

Corrosion:

The process of decay or disintegration or degradation of metal by environmental attack is called corrosion.

Example: Rusting of iron - Formation of reddish brown layer of rust on the surface of iron

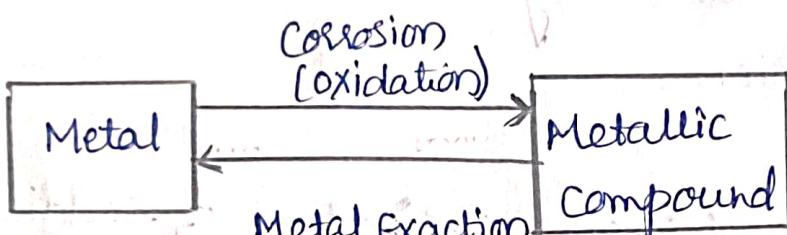


- Formation of green film of basic carbonate on the surface of copper. $[\text{CuCO}_3 + \text{Cu}(\text{OH})_2]$
- The corrosion of metals is measured in units of milliinches/year or mm/year.

causes of corrosion:

- During the extraction of metals ores are reduced to metallic state by supplying energy.
- Hence isolated pure metals are regarded as excited states than their corresponding ores.
- So metals have the natural tendency to go back to their combined state.
- As a result when the metal is exposed to environmental conditions like dry gas, moisture & liquids

→ The metal surface reacts and forms the more stable compounds of metals like oxides, carbonates etc.



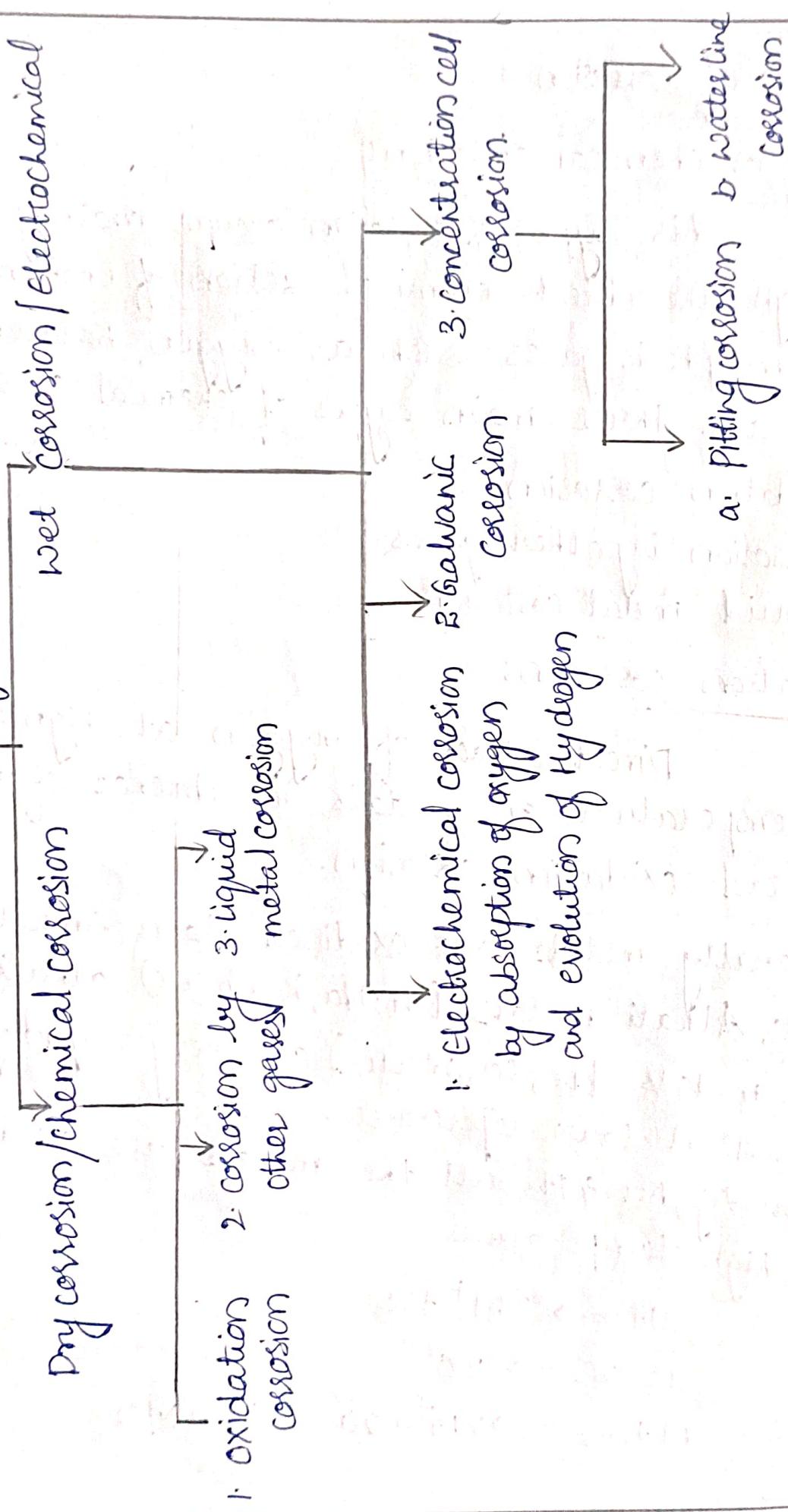
Thermodynamically unstable. Thermodynamically stable.

Effects or disadvantages of the corrosion process:

1. The valuable metallic properties like conductivity, malleability, ductility etc.
2. The process of corrosion leads to enormous wastage of metal in the form of its compounds.
3. Life span of the metallic parts of the machinery is reduced.
4. The failure of the machinery takes place due to loss of useful properties of metal.

Types of corrosion.

Corrosion of metals.



Theories of corrosion.

1. Dry or chemical corrosion:

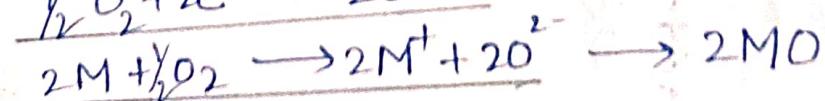
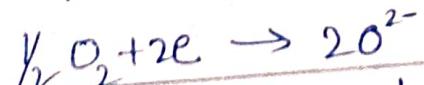
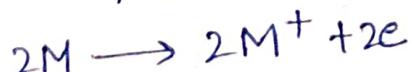
This type of corrosion occurs mainly through the direct chemical action of environment or atmospheric gases such as oxygen, halogens etc. There are three main types of chemical corrosion

- a) oxidation corrosion
- b) corrosion by other gases
- c) liquid metal corrosion

a. Oxidation corrosion:

Direct attack of oxygen at high or low temperature on metals in absence of moisture is called oxidation corrosion.

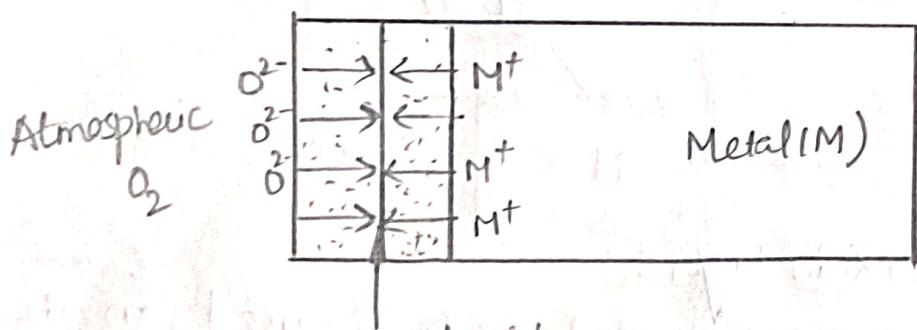
- Generally metals are oxidised to a smaller extent; Alkali metals (Li, Na, K, Rb etc.) alkali earth metals (Be, Ca, Sr etc.) are very rapidly oxidised at low temperature.
- except Ag, Au & Pt all the metals are oxidised at high temperature.



Mechanism of oxidation corrosion:

The oxidation of the metal occurs at the surface first, resulting in the formation of metal oxide scale, which restricts further oxidation.

→ Further oxidation can continue if the metal diffuse out of the scale or the oxygen must diffuse in through the scale to the underlying metal.

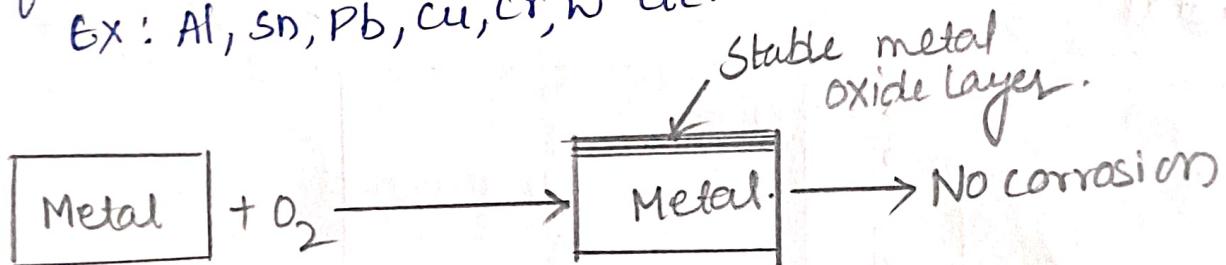


Nature of the metal oxide formed plays an important role in oxidation corrosion.

1. Stable metal oxide layer:

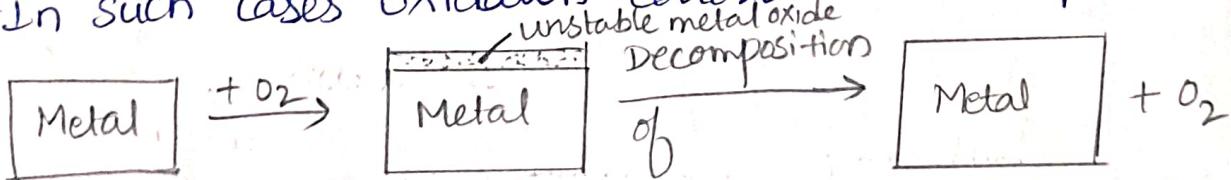
Metal oxide layer with fine-grained structure, tightly adheres to the metal surface is impermeable to the attacking oxygens. → such film behaves as protective coating in nature thereby shielding the metal from further corrosion

Ex: Al, Sn, Pb, Cu, Cr, W etc.



2. Unstable metal oxide layer:

unstable metal oxide formed on the metal surface decompose back into the metal. In such cases oxidation corrosion is not possible.

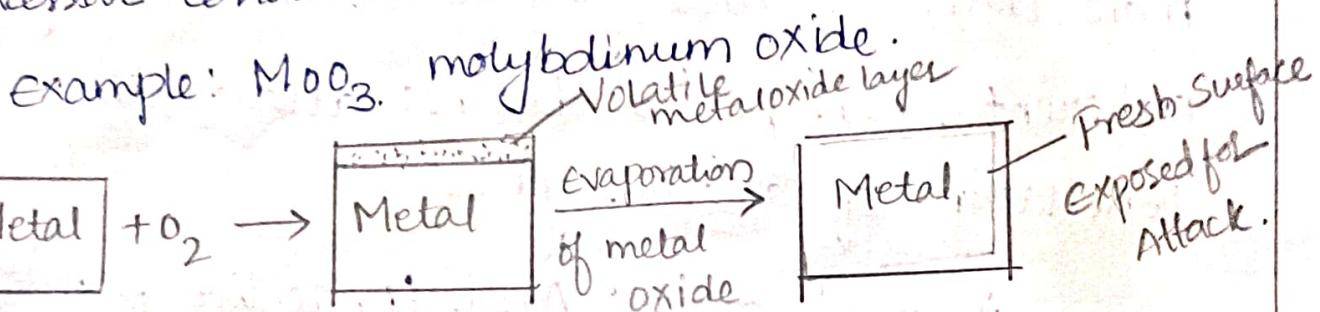


Example: Ag, Au & Pt do not undergo oxidation corrosion.

3. Volatile oxide layer:

volatile oxide layer formed during corrosion evaporates as soon as it is formed leaving the metal for further attack.

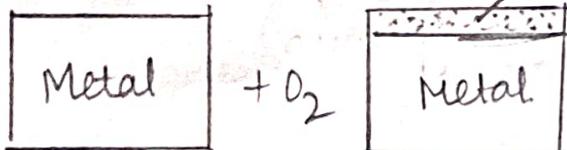
→ This cause rapid and continuous corrosion leading to excessive corrosion to occur.



4. A porous layer:

porous layer of metal oxide contains pores, cracks etc. provide access to oxygen to reach the underlying surface of metal. As a result the corrosion process continues, till the entire metal is completely converted to its metal oxide.

Ex: Alkali & Alkaline earth metals



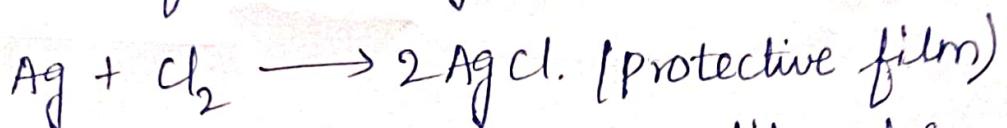
Further attack through pores and cracks continues.

b). Corrosion by other gases:

gases like SO_2 , CO_2 , Cl_2 , H_2S , and F_2 etc. also cause chemical corrosion and the extent of the corrosion mainly depends on the reactivity to the gas on the metal surface.

→ The degree of attack depends on the formation of protective or non protective films on the metal surface which is explained by pilling Bedworth rule.

i) If the volume of the corrosion film formed is more than the underlying metal, it is strongly adherent, non porous does not allow the penetration of corrosive gases



ii) If the volume of the corrosion film formed is less than the underlying metal, it form pores or cracks and allows the penetration of corrosive gas leading to corrosion of the underlying metal.

Ex: In petroleum industry H_2S gas at high temperature reacts with steel forming a FeS scale $\text{Fe} \text{ (steel)} + \text{H}_2\text{S} \text{ FeS (porous)}$

3. Liquid metal corrosion:

This corrosion is due to chemical action of flowing liquid metal at high temperature on solid metal or alloy.

→ The corrosion reaction involves either dissolution of a solid metal by a liquid metal or internal penetration of the liquid metal into the solid metal.

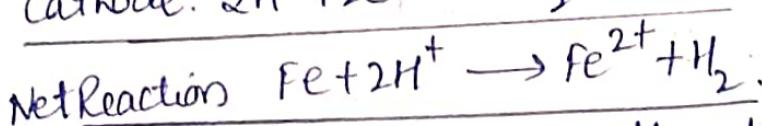
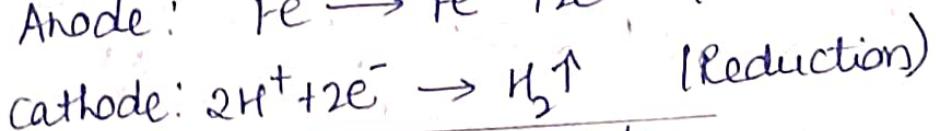
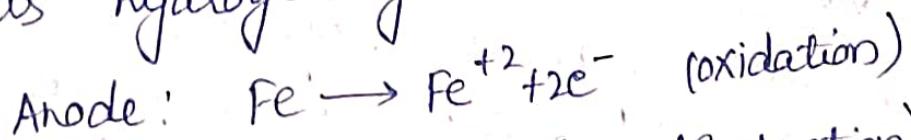
Eg: coolant (sodium metal) leads to corrosion of cadmium in nuclear reactor.

Wet or Electrochemical corrosion:

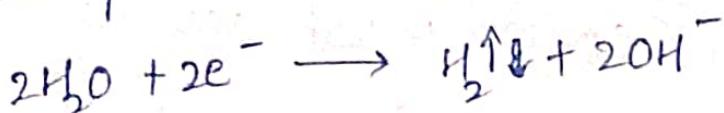
Wet corrosion take place under wet or moist conditions through the formation of electrochemical cells. It is more common than dry corrosion. It takes place by the following ways.

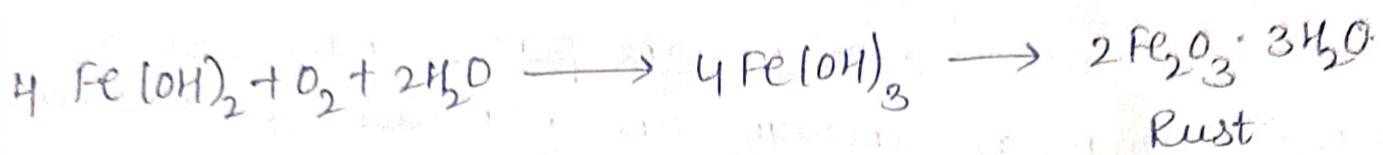
- a. Evolution of hydrogen
- b. Absorption of oxygen
- c) Evolution of hydrogen:

It usually occurs in acidic environment.
 At anode - the dissolution of iron to ferrous ion with liberation of electron take place
 $\rightarrow 2e^-$ flows from anodic to cathodic area through the metal, where H^+ are available and eliminated as hydrogen gas.

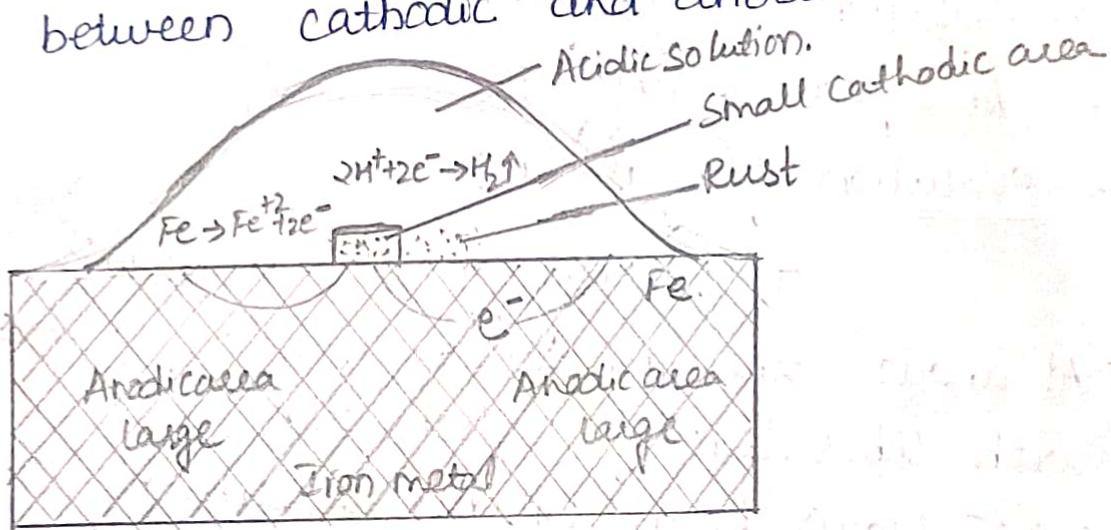


- \rightarrow The anodes are usually large and cathode are small.
- \rightarrow In neutral medium at cathode formation of OH^- take place.





Fe^{2+} and OH^- diffuse towards each other through the conducting medium, forming the corrosion product rust in between cathodic and anodic areas.

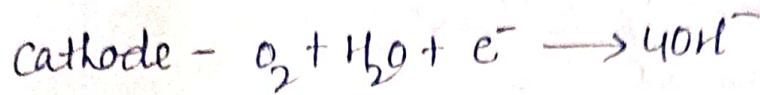
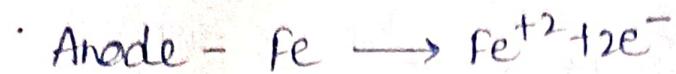


b. Absorption of oxygen :

In presence of neutral, aqueous solution of electrolyte, in presence of atmospheric oxygen some cracks developed in iron oxide film causes electrochemical corrosion.

- Surface of iron is coated with thin film of iron oxide, if a crack is developed, anodic areas are created on the surface.
- while the well coated metal acts as a cathode.
- small anodic areas and large cathodic areas are formed.

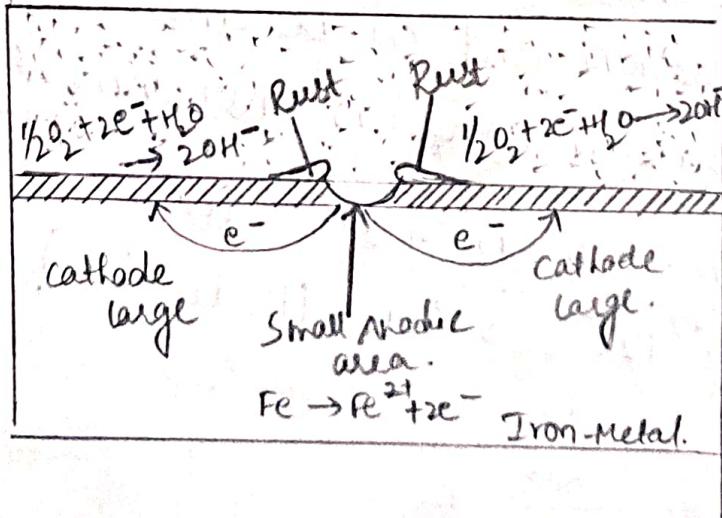
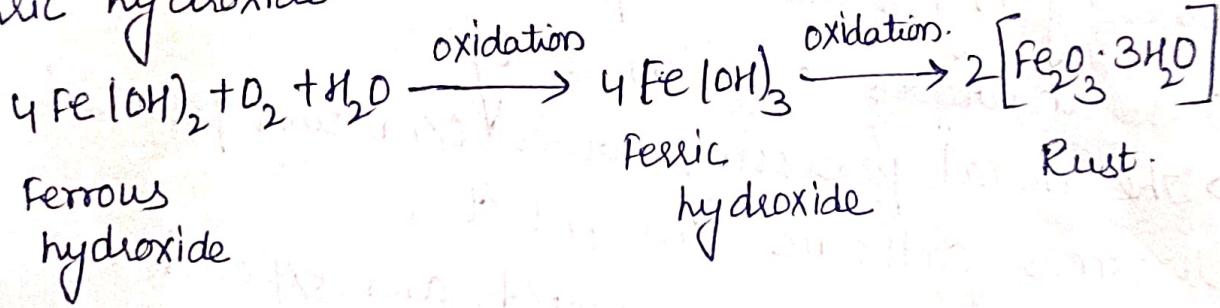
Reactions



Fe^{+2} ions and OH^- ions diffuse and forms rust when they meet.



If enough O_2 is present $Fe(OH)_2$ is easily oxidised to ferric hydroxide.



TYPES OF CORROSION:

The different types of corrosion.

a) Galvanic corrosion.

b) Waterline corrosion

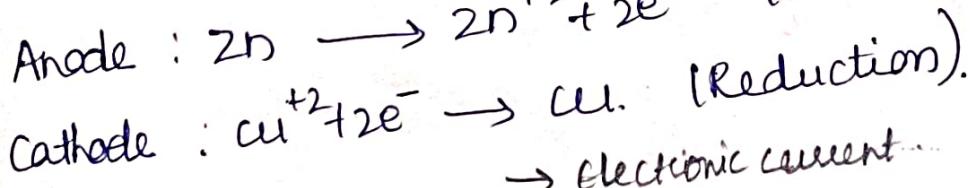
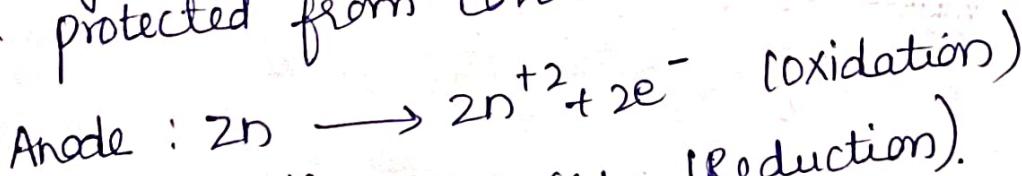
c) Pitting corrosion

i. Galvanic corrosion:

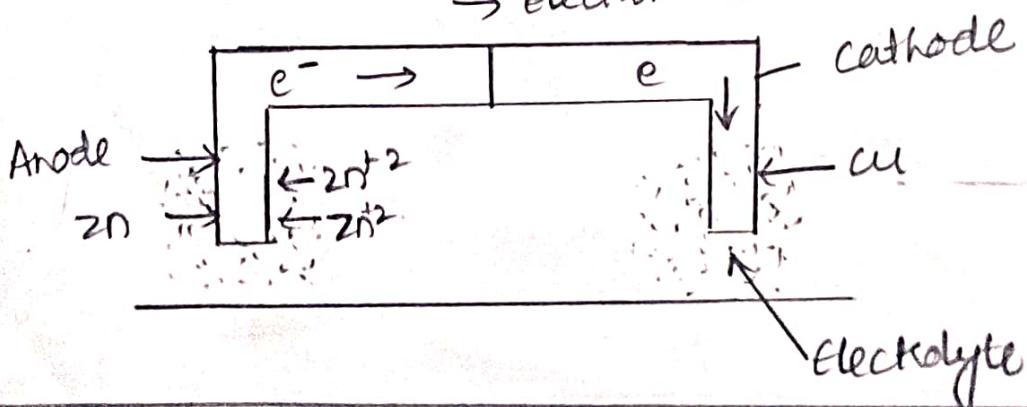
when two dissimilar metals are connected jointly and exposed to corrosive atmosphere, the metal possessing higher oxidation potential becomes anodic and undergoes corrosion easily.

→ The metal possessing lower oxidation potential becomes cathodic and protected

e.g. Zn and Cu are connected and exposed to corroding environment. Zn becomes anodic and undergoes corrosion and Cu becomes cathodic and get protected from corrosion environment.



→ Electronic current



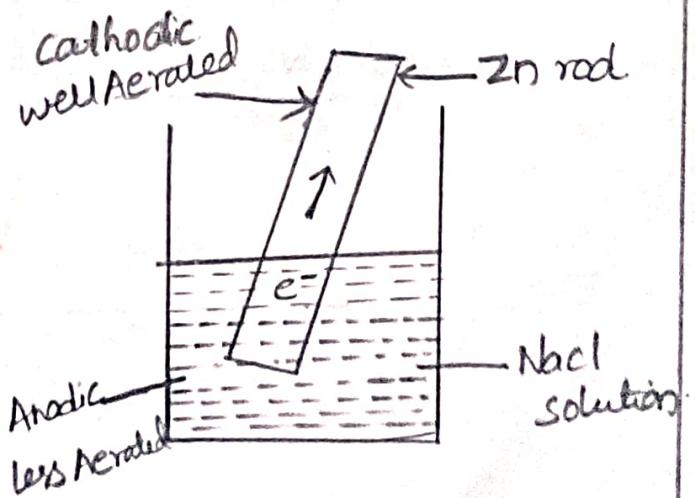
b). water line corrosion:

Water line corrosion is also differential aeration corrosion leading to the formation of oxygen concentration cell.

Example: 1. Water stored in a steel tank.

2: partial immersion of metal in a solution.

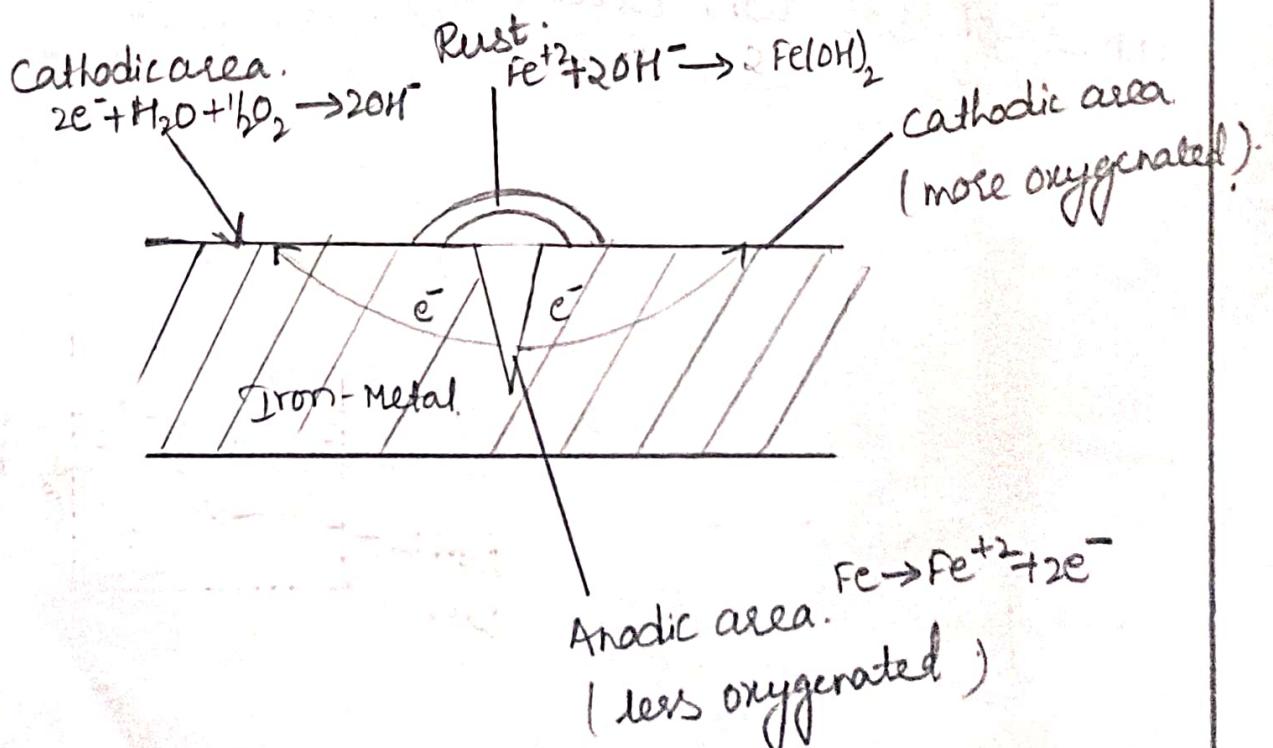
when a Zn rod is dipped in NaCl solution, where the rod in NaCl acts as anode and Zn rod above the NaCl solution act as cathode.
→ As a result Zn in NaCl solution undergoes oxidation and more corroded - this corrosion occurs at the line of solution called as water line corrosion.



Pitting corrosion:

A cavity, pin holes, pits and cracking of protective film developed on the metal surface creates the formation of small anodic areas in the less oxygenated parts and large cathodic areas in well oxygenated parts.

- The flow of electrons from anodic part to the cathodic part take place.
- The corrosion product is formed between cathodic and anodic area.



CATHODIC PROTECTION:

The method of protection given to a metal by forcibly making it to behave like a cathode is called cathodic protection. There are two types of cathodic protection.

1. Sacrificial anodic protection.
2. Impressed current cathodic protection.

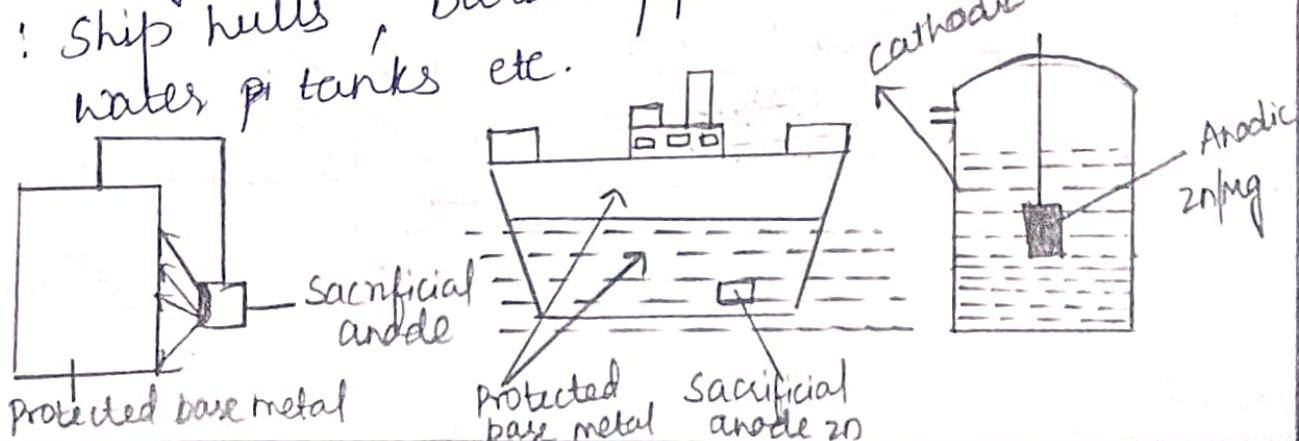
1. Sacrificial anodic protection.

In this method, the metallic structure to be protected called 'base metal' is connected to more anodic metal which is having higher oxidation potential to the base metal.

→ Anodic metal undergoes corrosion slowly while the base metal is protected.

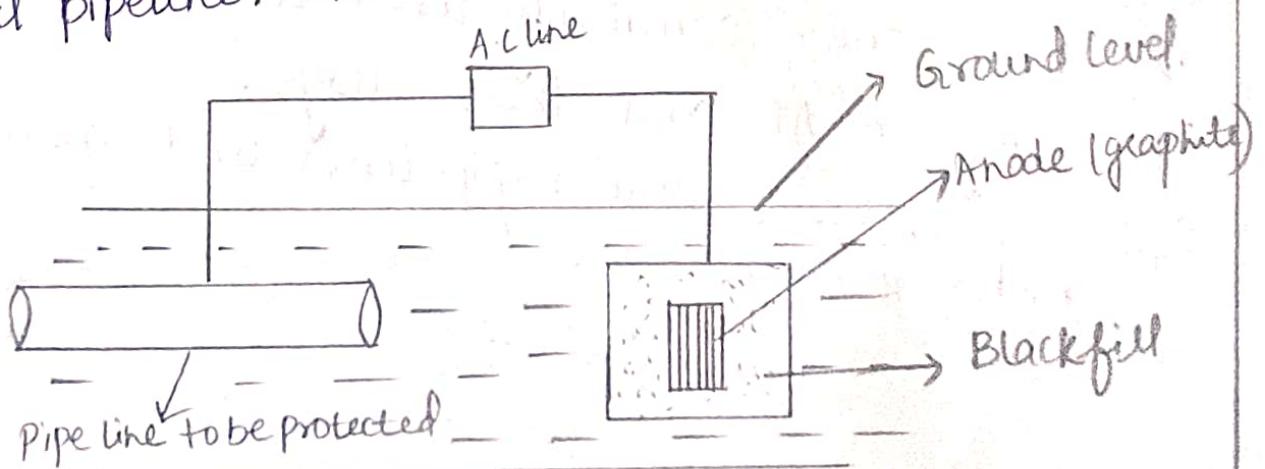
→ The corroded sacrificial anode block is replaced by fresh one. commonly used anodic metals are Mg, Zn, Al. and their alloys.

Eg: Ship hulls, buried pipelines, underground cables, water pi tanks etc.



b. Impressed current cathodic protection:

In this method an impressed current little more than corrosion current is applied in opposite direction to nullify the corrosion current producing a reverse cell reaction
→ Thus the anodic metal becomes cathodic and protected from corrosion.
→ The impressed current is taken from a battery or A.C line. Anode is usually insoluble like graphite, high silica, iron, scrap iron, stainless steel.
→ Sufficient direct current is passed to the insoluble anode kept in a back fill composed of coke or gypsum to increase the electrical contact with the surrounding soil.
eg: open water box coolers, water tanks, buried water or oil pipeline, etc



(2)

Comparision of chemical corrosion with electrochemical corrosion.

S.NO	Dry or chemical corrosion	Wet or Electrochemical corrosion
1.	This corrosion occurs at dry conditions.	This corrosion occurs in wet condition in presence of an electrolyte medium.
2.	Corrosion is uniform	Corrosion is not uniform if the anodic area is small, pitting is more frequent.
3.	It is a slow process.	It is a rapid process.
4.	It involves direct chemical attack of the metals by environment	It involves the formation of large number of electro-chemical cells.
5.	It is explained by absorption mechanism.	It is explained by mechanism of electrochemical reactions.
6.	It occurs both on homogeneous and heterogeneous solutions.	It take place only on heterogeneous processes.
7.	Corrosion products are produced at the place where corrosion takes place.	Corrosion occurs at the anode and corrosion product occurs in between cathodic and anodic areas.