LECTURE NOTES

ON

CORROSION SCIENCE

ENGINEERING CHEMISTRY

B.Tech 1st year

By

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Content

1. Introduction

What is corrosion? Corrosion (irreversible process) is a natural process in which pure metal (unstable) except noble metals is converted into chemically stable compounds like oxides, sulphide, hydroxide, carbonates etc. or The process of slowly deterioration of the metal due to attack of atmospheric gases on the surface of metal resulting into the formation of more stable compounds such as oxides, sulphide, carbonates etc. is known as Corrosion. The most common corrosion is rusting of Iron ($Fe_2O_3.xH_2O$).

2. Factor affecting Corrosion

a) Reactivity of metal:
   If metal is more reactive then it undergoes corrosion more readily.
b) Strain in metal:
   Corrosion takes place readily at cuts and bends area of metal.
c) Presence of impurities:
   If impurities present in the pure metal then metal undergoes corrosion more readily.
d) Presence of electrolyte:
   In saline water (electrolyte) metal readily corrodes.
e) Air and moisture:
   Best example rusting of Iron.
f) pH:
   pH< 7 is more corrosive than basic or neutral medium.
g) Temperature:
   At higher temperature rate of corrosion become increased.

3. Electrochemical theory of corrosion (Wet theory of Corrosion)

When metals are exposed to air, moisture, soil etc. then they undergoes corrosion through electrochemical process. In this process a separate anode and cathode areas are form on the metal surface. Corrosion always occurs at the anodic areas of metal through oxidation reaction and release electron. The liberated electron from anode, move towards cathode, where reduction take place. The overall theory is known as **electrochemical theory of corrosion**. It is also known as Wet theory of corrosion because corrosion takes place in presence of moisture. The flow of free electrons in this corrosion takes place through following processes:

a) Hydrogen Liberation
b) Absorption of Oxygen

a) Hydrogen Liberation:

This type of corrosion evolution of hydrogen occurs in acidic medium. Let's considering the metal Fe, anodic reaction is dissolution of iron as ferrous ions with Liberation of electrons.

At Anode

$$Fe \longrightarrow Fe^{2+} + 2e^{-} \text{ (Oxidation)}$$

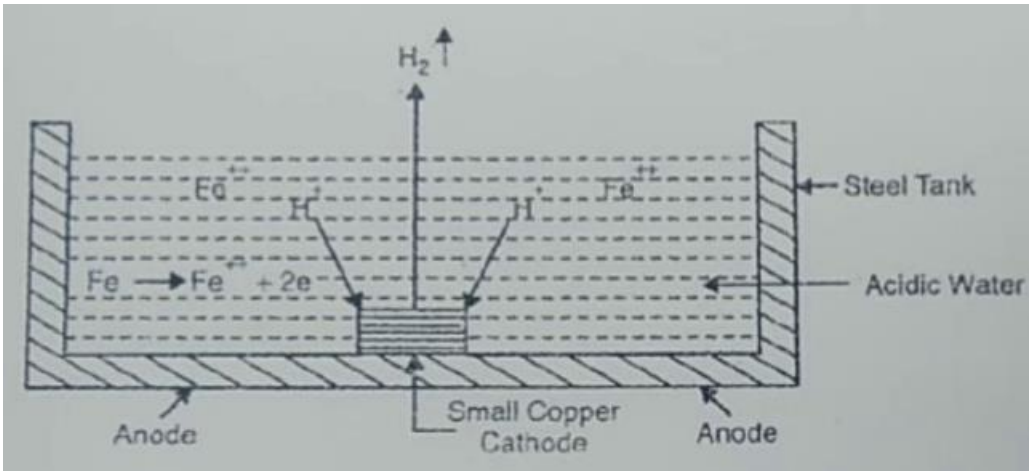
The electrons released flow through the metal from anode to cathode, whereas H+ ions of acidic solution are eliminated as hydrogen gas.

At Cathode

$$2H^{+} + 2e^{-} \longrightarrow H_2 \text{ (Reduction)}$$

The overall reaction is:

$$Fe + 2H^{+} \longrightarrow Fe^{2+} + H_2 \uparrow$$



b) Absorption of Oxygen:

The rusting of iron takes place in neutral aqueous solution of electrolytes (presence of atmospheric oxygen). If the metal surface develops cracks, anodic areas are created on the surface whereas the metal parts act as cathodes.

At anode

$$Fe \longrightarrow Fe^{2+} + 2e^{-} \text{ (Oxidation)}$$

The released electrons flow from anode to cathode through iron metal.

At cathode

$$\tfrac{1}{2} O_2 + H_2O + 2e^{-} \rightarrow 2OH^{-} \text{ (Reduction)}$$

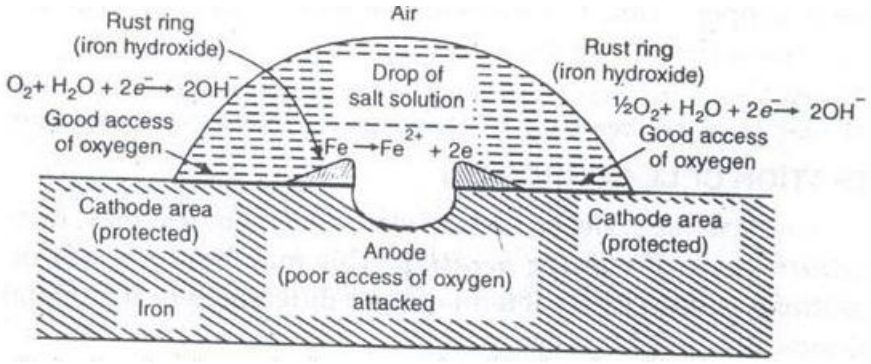
$Fe(OH)_2$ precipitate when Fe^{2+} and OH^{-} ions reacts with each other

$$Fe^{2+} + 2OH^{-} \longrightarrow Fe(OH)_2$$

If oxygen is in excess, ferrous hydroxide is easily oxidized to ferric hydroxide.

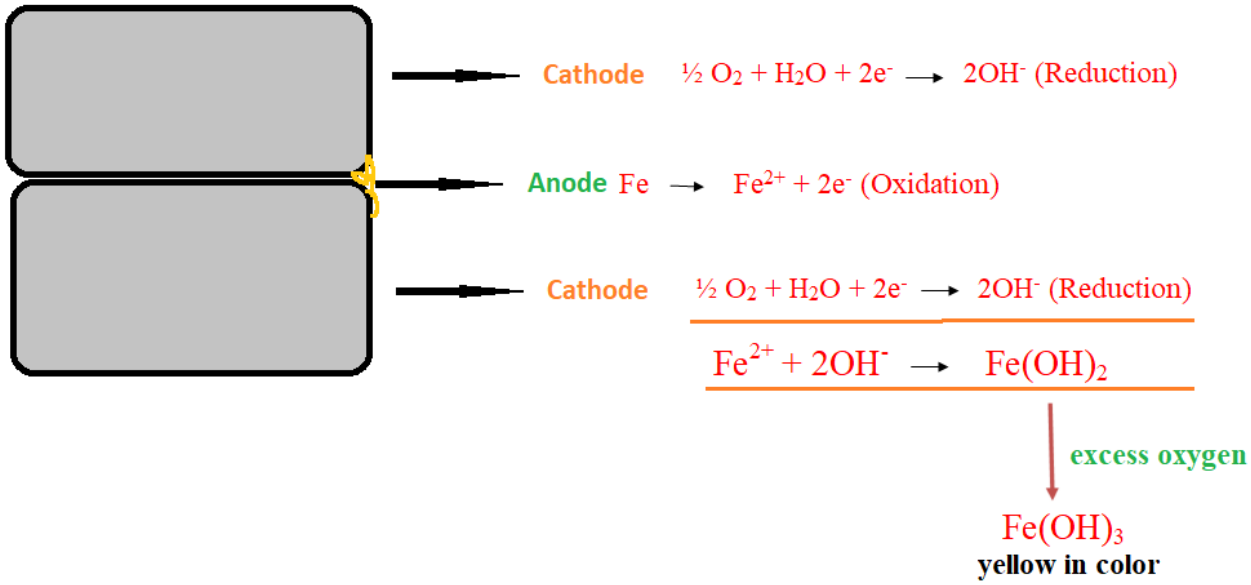
$$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4\,Fe(OH)_3$$

The yellow product form rust of Iron ($Fe_2O_3.\ 3H_2O$)



4. Crevice Corrosion

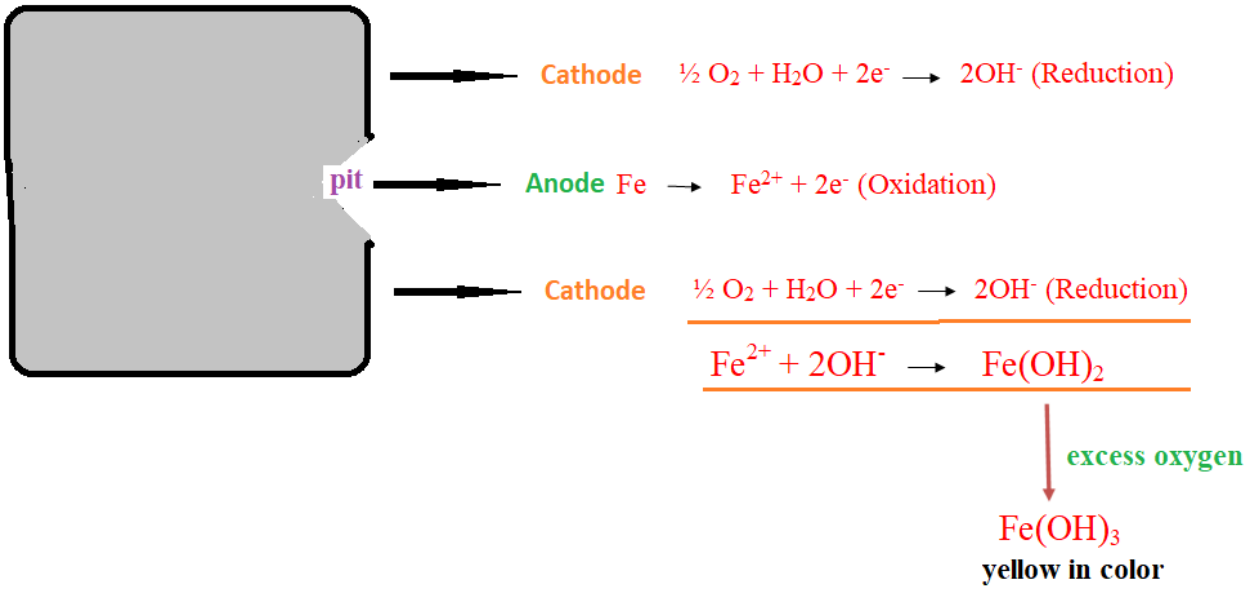
Crevice corrosion occurs between two joining surface which may be metal-metal or metal-nonmetal crevice. It is localized corrosion of metal or alloy surface. In crevice corrosion, the joining surface area has low concentration of oxygen as compare to other area. The portion with lower concentration of oxygen become anode and portion with higher concentration of oxygen becomes cathode. Mechanism of corrosion is similar to absorption of oxygen step of electrochemical theory of corrosion.



5. Pitting Corrosion

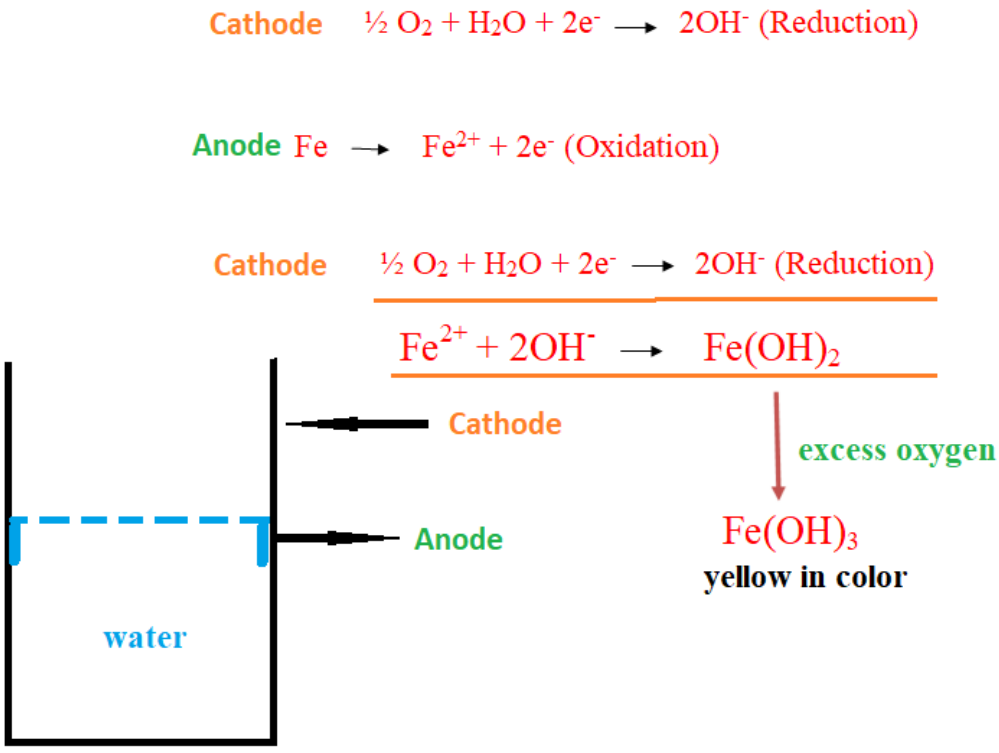
In pitting corrosion, a pit is formed when the protective coating on the metal surface break, a micro pit (anode) formed on the metal surface. Once the pit is form the process of corrosion become very fast due to different amount of oxygen in contact

with metal surface. The portion (pit) with lower concentration of oxygen become anode and portion with higher concentration of oxygen becomes cathode.



6. Water-line corrosion

When water is stored in the steel tank, then corrosion starts, along the line beneath the level of water meniscus. As we know that beneath the water level concentration of oxygen is very low therefore metal part below the water level acts as anode and metal part above the water level have higher concentration of oxygen therefore this region act as cathode. The reaction involve are as follows:



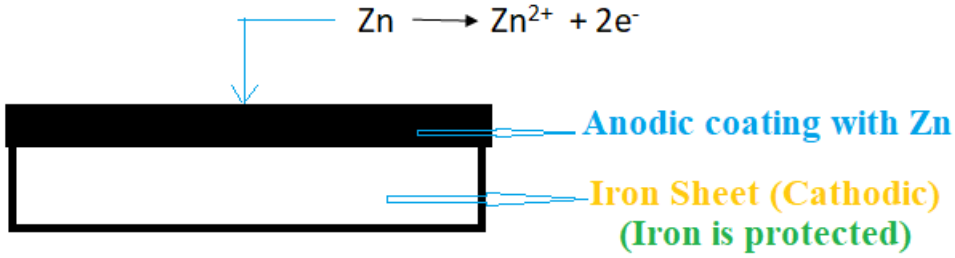
7. Corrosion Prevention

a) Metal Coating

In order to protect base metal form corrosion metal coating process has been adopted. The coating of metal can be achieved by following processes.

i) Anodic metal coating (Galvanization):

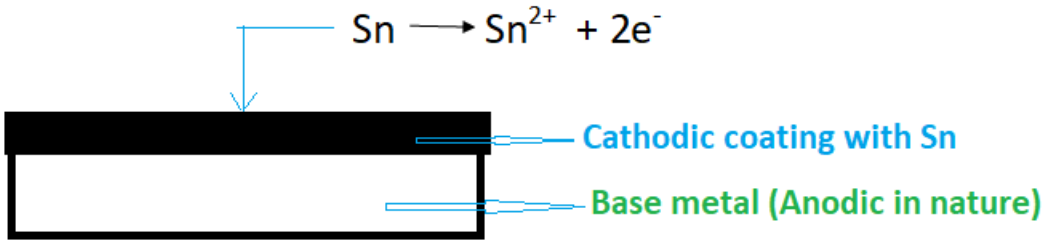
Metal coating which is anodic to base metal, known as anodic metal coating. In order to protect a metal from corrosion, any metal (anodic in nature) which is higher in the galvanic series like Zn is coated on the surface of metal (base metal/ cathodic in nature).



The best example of anodic metal coating is Galvanization. Galvanization is a process in which coating of base metal (to be protected) takes place by dipping the base metal (cathodic in nature) into the molten zinc (anodic in nature).

ii) Cathodic metal coating (Tinning):

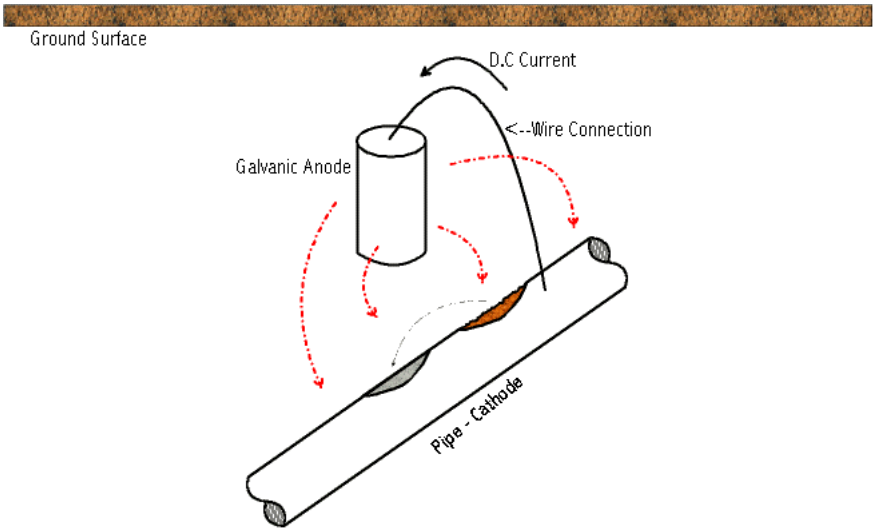
Metal coating which is cathodic to base metal, known as cathodic metal coating. In order to protect a metal from corrosion, any metal (cathodic in nature) which is lower in the galvanic series like Sn, Cu, Ni etc, are coated on the surface of metal (base metal/ anodic in nature).



The best example of cathodic metal coating is Tinning. Tinning is a process in which coating of base metal (to be protected) takes place by dipping the base metal (anodic in nature) into the molten Tin (cathodic in nature).

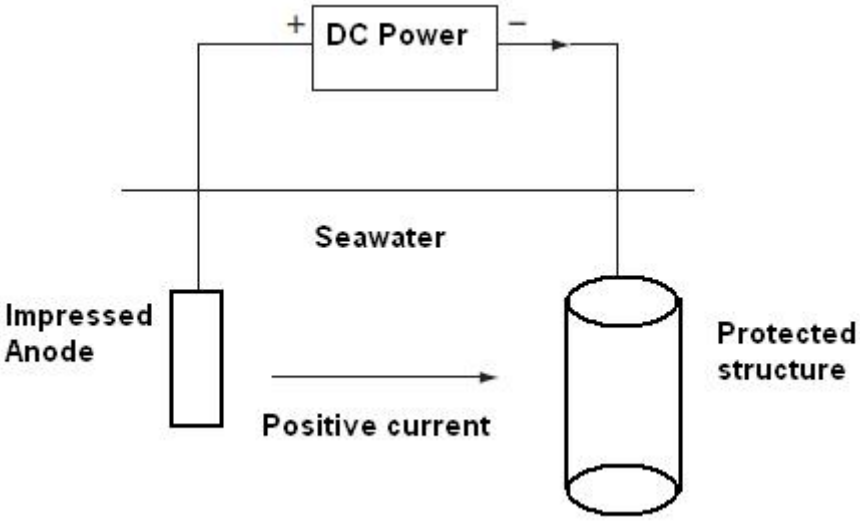
b) Scarification anodic protection:

In this protection method, the metallic structure to be protected (base metal) is connected by a wire to a more anodic metal so that all the corrosion occurs at that anodic metal and metallic structure (cathode) is protected. The more active metal so employed is called sacrificial anode. The corroded sacrificial anode is replaced by a fresh one, when consumed completely. Metals commonly employed as sacrificial anode are Mg, Zn, Al and their alloys which possess low reduction potential (more reactive) and occupies higher end in electrochemical series. The underground water pipelines and water tanks are also protected by sacrificial anode method.



c) Impressed cathodic protection:

In this method, an impressed current from external source is applied in opposite direction to neutralize the corrosion current, and convert the corroding metal from anode to cathode. Thus the anodic corroding metal becomes cathodic and protected from corrosion. The impressed current is deriving from the external DC source. The negative terminal of DC source is connected with metal to be protected whereas the positive terminal of DC is connected to the anode. Here anode may be graphite, stainless steel scrap iron etc. The impressed current protection method is used for water tanks, water & oil pipe lines, transmission line towers etc.



d) Electroplating:

In electroplating, electro-deposition of metal (anode) by means electrolysis over surface of metals and alloys (cathode or base metal). The two electrodes are dipped in the electrolyte solution which contains the metal ions to be deposited on the base metal. When a direct current is passed from an external source, the coating metal ions migrate towards cathode and get deposited over the surface of base metal in the form of a thin layer. In electroplating metal like Au, Ag, Zn, Sn, Cr, Ni etc. can be placed on the surface of base metal (Cathode).