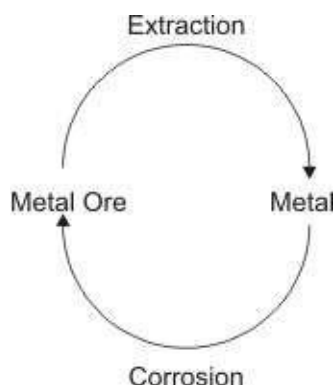


Corrosion and its Control

Corrosion is defined as the gradual destruction of metals or alloys by the surrounding environment through chemical or electrochemical changes.



Corrosion may occur either in dry environment or in aqueous medium. Depending on the environment it can be classified into i. Dry Corrosion ii. Wet Corrosion

Dry Corrosion: It is due to direct attack of metals by dry gases.
Ex: Attack of dry air or Oxygen on a metal to form oxide layer.

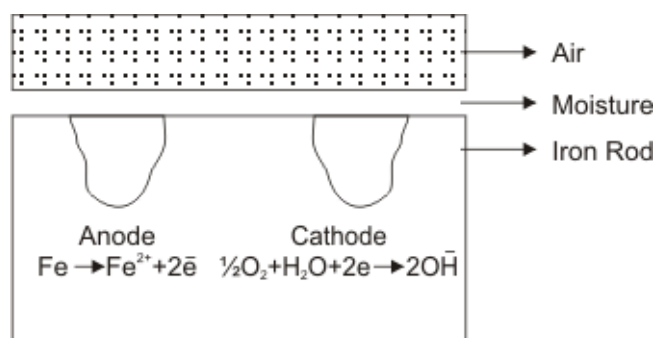
Wet Corrosion: In this type of corrosion metal undergoes electrochemical reaction with moisture and oxygen present in the atmosphere.

Ex: Rusting of Iron.

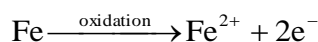
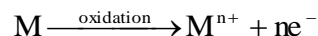
Mechanism of wet corrosion is explained on the basis of electro-chemical theory of corrosion

Electrochemical Theory of Corrosion

According to this theory, when a metal exposed to acidic environment medium, the following changes occur:



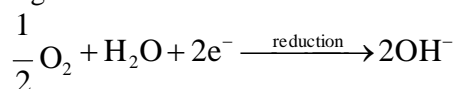
- Anodic and Cathodic areas are formed resulting in the formation of minute galvanic cells.
- Oxidation of metals takes place at the anodic region



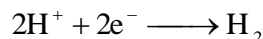
- Electrons flow from anodic region to the cathodic region and causes reduction.

There are three possible ways in which the reduction can takes place:

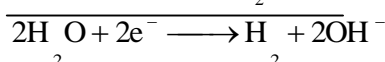
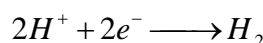
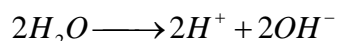
- If the solution is aerated, oxygen get reduced to OH^{-} ions in the presence of water at cathodic region.



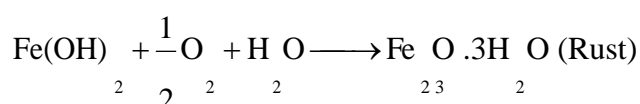
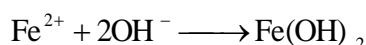
- If the solution is deaerated, and acidic, the H^{+} ions get reduced to H_2



- If the solution is deaerated, water get reduced to H_2 and OH^{-} .



The metal ions formed at the anode combine with OH^{-} ions formed at cathode to form the metal hydroxide and finally hydrated metal oxide (rust).



Different types of wet corrosion:

According to electrochemical theory, corrosion is due to formation of large number of minute galvanic cells. There are different ways in which a galvanic cell can be formed on the metal surface.

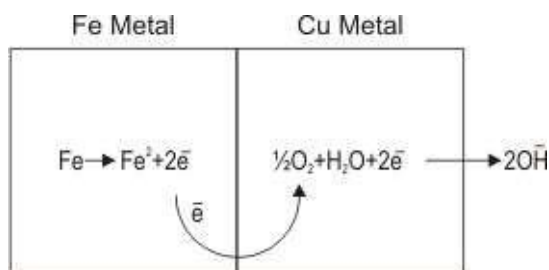
Depending on the ways in which galvanic cell can be formed, following types of corrosion have been observed.

- i. Differential metal corrosion
- ii. Differential aeration corrosion
- iii. Stress corrosion

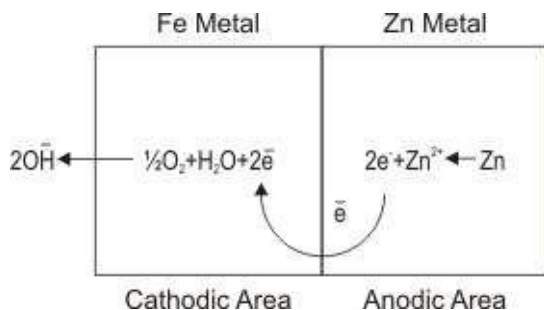
i. Differential metal corrosion:

When two dissimilar metals are in contact with each other, the metal with the lower reduction potential becomes anodic and undergoes corrosion. Whereas, the metal with higher reduction potential becomes cathodic and remains unaffected. This kind of corrosion is called as differential metal corrosion.

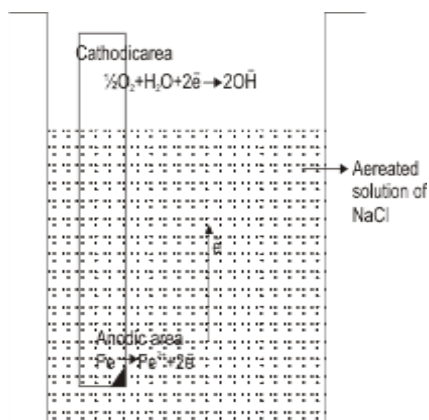
The rate of corrosion depends mainly on potential difference between two metals. Higher the difference, faster is the rate of corrosion.



Standard potential of Fe (-0.44 V) is less than that of Cu (0.34 V). Therefore, when iron is in contact with copper, iron acts as anode and undergoes corrosion whereas copper acts as cathode and remains unaffected.



Standard potential of Zn (-0.76 V) is less than that of Fe (-0.44 V). Therefore, when iron is in contact with zinc, zinc undergoes corrosion whereas iron remains unaffected.

ii. Differential aeration corrosion:

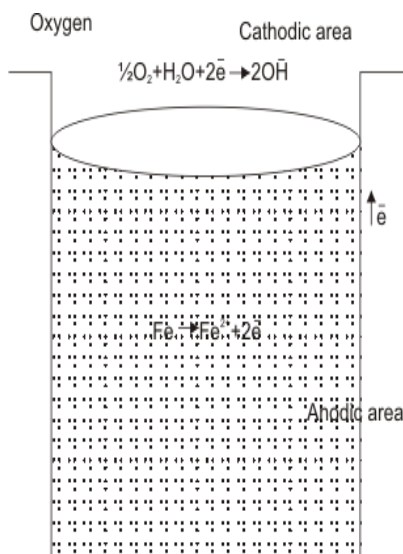
When a metal exposed to different concentration of air (O_2). Part of the metal exposed to lower concentration of O_2 becomes anodic and undergoes corrosion. Whereas, other part of the metal which is exposed to higher concentration of O_2 becomes cathodic and remains unaffected. This kind of corrosion is called as differential aeration corrosion.

Iron rod partially immersed in NaCl solution. Part of the metal immersed in solution is exposed to lower concentration of O_2 becomes anodic and undergoes corrosion. Whereas, part of the metal outside water is exposed to more concentration of oxygen becomes cathodic and remains unaffected.

The best examples for differential aeration corrosion are:

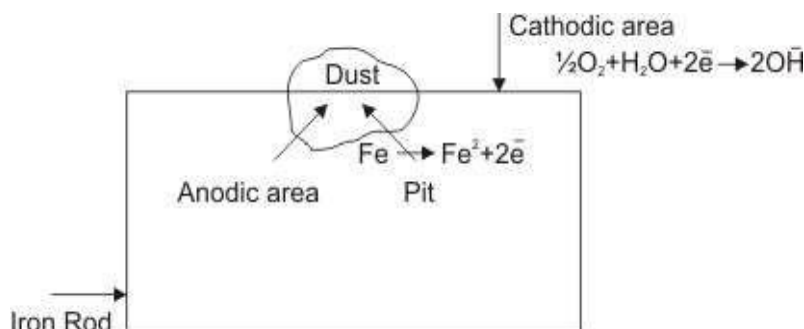
- Water line corrosion
- Pitting corrosion

Water line corrosion:



It is observed in iron or steel tank partially filled with water. Metal just below water line which is exposed to lower concentration of O_2 , becomes anodic and undergoes corrosion, whereas metal just above the waterline which is exposed to higher concentration of O_2 becomes cathodic and remains unaffected.

Pitting corrosion:



In this type of corrosion, when dust particles or oil drops get deposited over the metal surface. The portion of the metal covered by dust which is less exposed to O_2 becomes anodic and undergoes corrosion. Whereas, the portion of the metal which is not covered by dust is exposed to higher concentration of O_2 becomes cathodic and remains unaffected.

Write a note on factors affecting rate of corrosion:

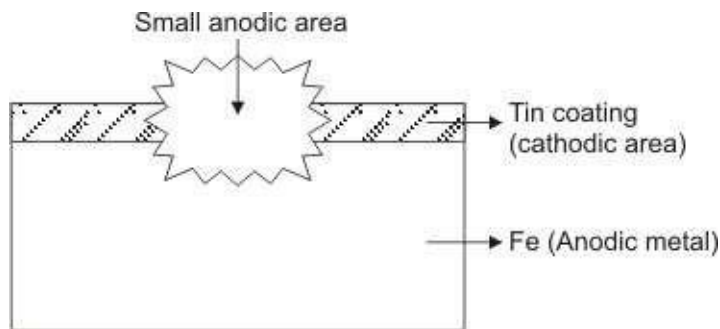
- Primary factors
- Secondary factors

Primary factors: These factors are related to the nature of the metal

- Electrode potential:** This is the key factor in deciding the rate of corrosion in differential metal corrosion. When two dissimilar metals are in contact with each other, one with lower potential becomes anode and other with higher potential becomes cathode. The rate of corrosion depends on the difference in potential between cathodic and anodic areas.

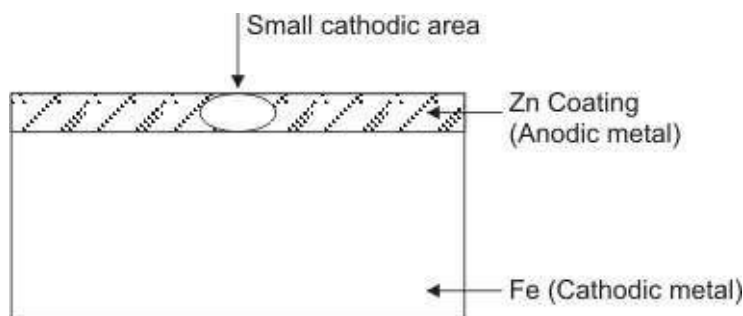
Ex: Potential difference between Iron and copper is (0.78 V). Potential difference between Iron and tin is (0.3 V). Therefore iron corrodes faster with copper than with tin.

- Relative size of the anodic and cathodic areas:** Smaller the anodic area and larger the cathodic area, then more intense and faster will be the corrosion at anodic area. When cathodic area is large, demand for electrons for reduction reaction is high. To meet this demand, oxidation reaction occurs more intensely at anodic area.



Ex: In case of coating tin on iron, if some area is not covered, a small anodic area and large cathodic area are formed. In this case rate of corrosion of iron becomes higher than that under normal conditions.

On the other hand, if anodic area is large and cathodic area is small, then the rate of corrosion at anodic area will be very low.



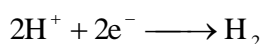
In case of coating zinc on iron, if some areas are not covered, a small cathodic and large anodic area are formed. In this case rate of corrosion of iron metal becomes lower.

iii. Nature of corrosion product: Most of the metals form their oxides as their corrosion product. This oxide forms the thin film on the surface of the metal and its nature decides the extension of further corrosion. If the corrosion product is stoichiometric in composition, highly insoluble, non-porous with low ionic and electronic conductivity, then the oxide layer effectively prevents further corrosion. (Al, Ti, Cr, Metal coating prevents corrosion)

If the corrosion product is non-stoichiometric in composition, highly soluble, porous, with higher ionic and electronic conductivity, then further corrosion of metal can't be prevented.

Secondary factors: These are related to the nature of environment in which metal is used

- i. pH:** The rate of corrosion increases with decrease in pH. If the pH is < 3 , greater corrosion occurs even in the absence of air due to evolution of hydrogen at cathode.



If the pH is between 3 and 10, the presence of oxygen is essential for corrosion of metal.

- ii. Temperature:** Rate of corrosion increases with increase in temperature. Because, as the temperature increases, conductance of the ions increases in the aqueous medium. Therefore rate of corrosion also increases.

Corrosion control:

Corrosion of metal occurs mainly due to interaction of metal surface with O_2 and moisture in the atmosphere. This can be prevented by coating a protective layer over the surface of the metal. The following methods are commonly used to control corrosion:

I. Protective coatings

1. Inorganic coatings

a) Metal coatings

- i. Anodic metal coating
- ii. Cathodic metal coating

b) Surface conversion coatings

- i. Anodizing
- ii. Phosphating

II. Cathodic protection

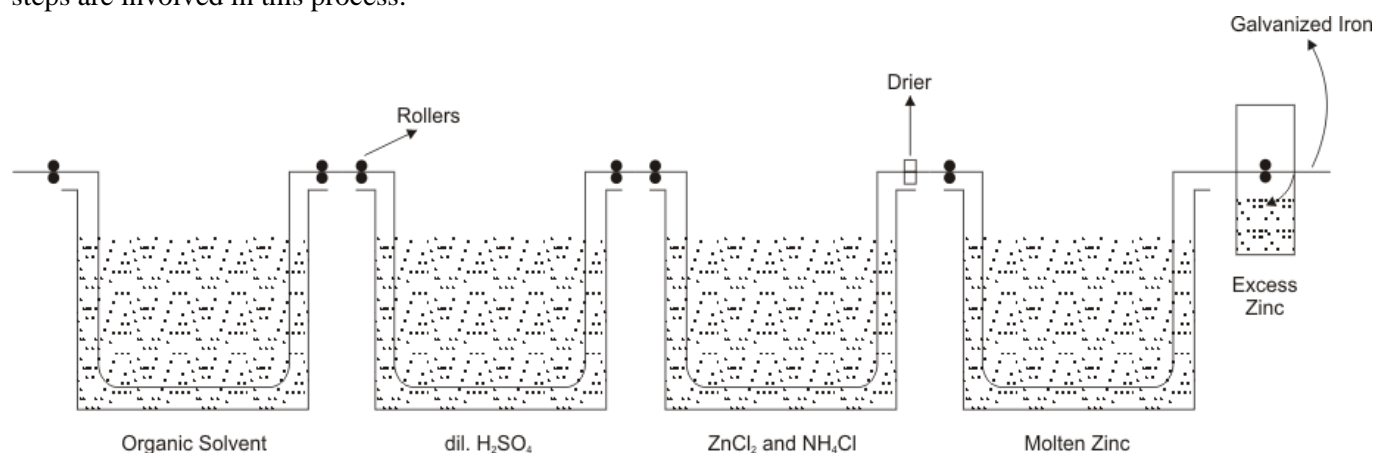
Metal coatings: In this case, corrosion of the base metal is prevented by coating a layer of another metal over it. Metal coated may be anodic or cathodic to the base metal.

- i. Anodic metal coating: In this type of coating, coating a layer of metal which is anodic to base metal.

Ex: Coating of Zn or Mg or Cd metal on iron.

Galvanizing is an example for anodic metal coating

Galvanizing: The process of Coating a layer of zinc on iron by hot dipping is called galvanization. The following steps are involved in this process:



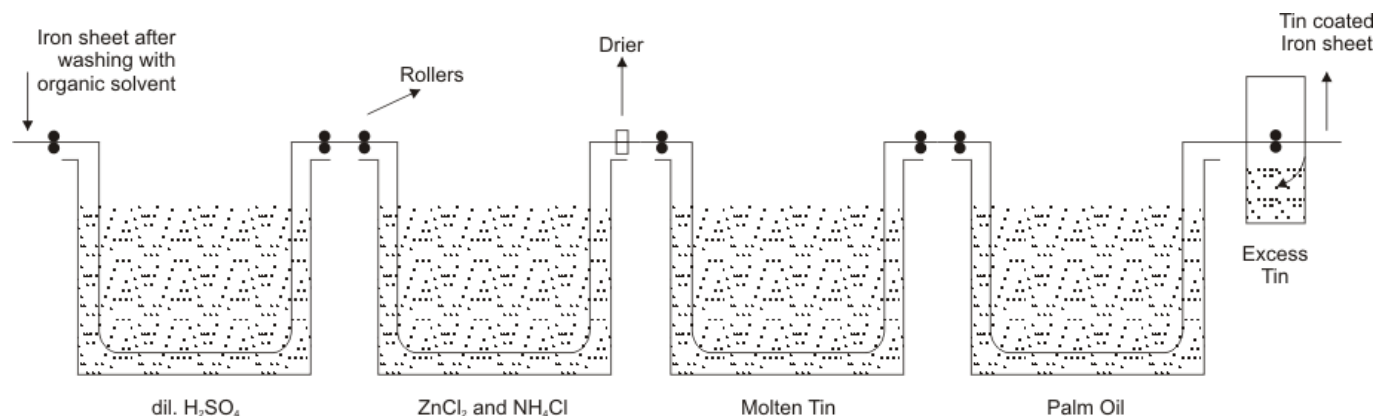
- i. Iron sheet is passed through organic solvent to remove oil or grease present over it.
- ii. Then, it is washed with dil. H₂SO₄ to remove any rust (Oxide layer) present on the surface.
- iii. Then it is treated with a mixture of aqueous solution of ZnCl₂ and NH₄Cl which acts as flux and then it is dried.
- iv. Finally it is dipped in molten zinc at 450° C.
- v. Excess zinc present on iron sheet is removed by passing through rollers.

Cathodic Metal coating: In this type of coating, coating a layer of metal which is cathodic to base metal.

Ex: Coating of tin or Ni metal over iron.

Tinning is an example for Cathodic metal coating

Tinning: The process of coating a layer of tin metal on iron by hot dipping is called tinning. The following steps are involved in this process:



- Iron sheet is passed through organic solvent to remove oil or grease present over it.
- Then, it is washed with dil. H_2SO_4 to remove any rust (Oxide layer) present on the surface.
- Then it is treated with a mixture of aqueous solution of $ZnCl_2$ and NH_4Cl which acts as flux and then it is dried.
- Finally it is dipped in molten tin at $330^\circ C$.
- Excess tin present on iron sheet is removed by passing through rollers and then immersed in palm oil to prevent surface oxidation of tin.

II. Cathodic protections: Corrosion of the metal occurs at anodic area, where metal is oxidized liberating electrons. These electrons flow to the cathodic area of the metal which remains unaffected.

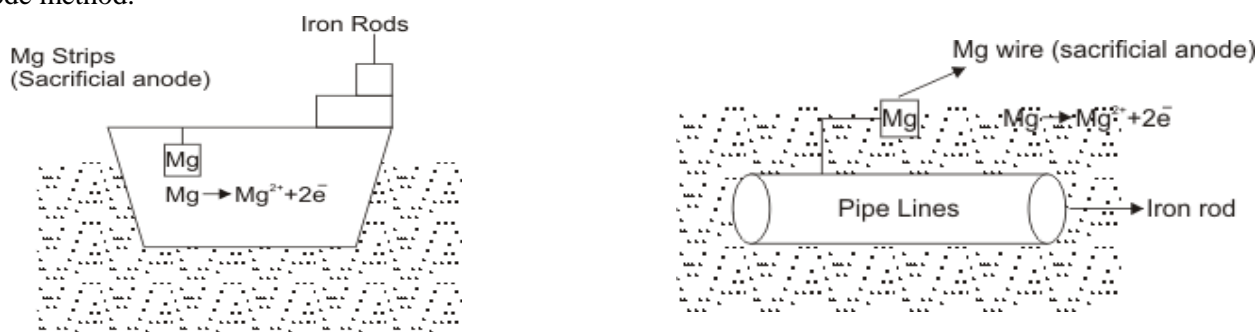
In cathodic protection, electrons are supplied from an external source to prevent the oxidation of metal at anodic area and thus making whole metal cathodic. When whole metal become cathodic it doesn't undergo corrosion.

“The process of protecting a metal against corrosion by making whole metal cathodic by providing electrons from an external source is called as cathodic protection.”

Two important cathodic protections are:

- Sacrificial anode method
- Impressed current (Voltage) method

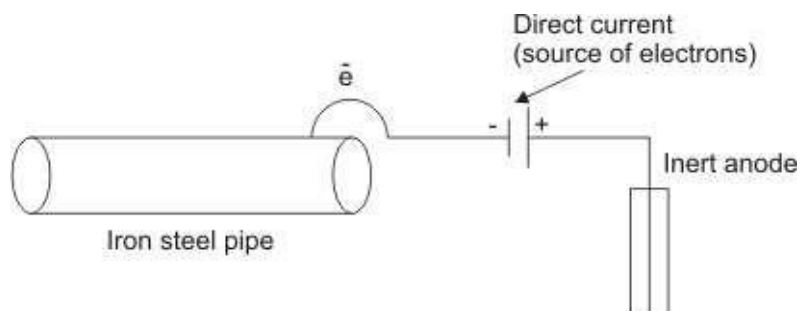
Sacrificial anode method: In this method, the protected base metal is converted into cathode by connecting it to a more active metal. This active metals like Zn, Al and Mg acts as anodic to base metal and undergo preferential corrosion. Since, the anodic metals are sacrificed to protect the metal structure, the method is known as sacrificial anode method.



Ex: When steel is protected, it is connected to a block of Mg or Zn. In such case, steel acts as cathode and it is unaffected where as Mg or Zn acts as anode and undergoes sacrificial corrosion.

This method is used to protect buried pipelines, ships, water tanks, iron rods.

Impressed current method: In this method, the electrons are supplied from a direct current source. Metal specimen which is to be protected is connected to -ve terminal of DC source. The +Ve terminal of the source is connected to inert electrode like platinised titanium or tantalum.



To prevent anodic reaction, potential greater than the potential of anodic reaction is applied in the reverse direction. Thus, whole metal becomes cathodic and hence protected from corrosion. This method is used for protecting water tanks, marine structures.
