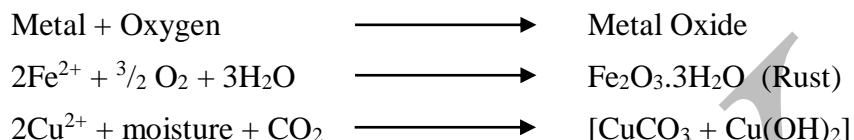


CORROSION

INTRODUCTION:

The surface of almost all metals begins to decay more or less rapidly, when exposed to gaseous atmosphere, water or another reactive liquid medium. As a result of the decay, the metals are converted to their oxides, hydroxides, carbonates, sulphides etc.

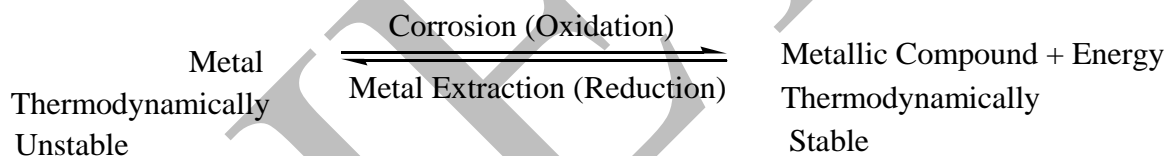
The process of decay of metal by environmental attack is called **CORROSION**. Ex: Formation of a layer of reddish scale of hydrated ferric oxide on the surface of iron is also called '**Rusting Of Iron**' and formation of green film of basic carbonate on the surface of copper are the most common and familiar examples of corrosion.



The corrosion of metals is measured in the units of milli-inches/year or mm/year.

CAUSES OF CORROSION:

The basic reason for this attack is most of the metals (except Pt, Au) exist in nature in the form of their minerals or ores, in the stable combined forms as oxides, chlorides, silicates, carbonates, sulphides etc. during extraction of metals these ores are reduced to metallic state by supplying considerable amounts of energy. Hence the 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 (ores/minerals). As a result when metal is exposed to environmental conditions like dry gases, moisture and liquids etc., the metal surface reacts and forms the more stable compounds of metals like oxides, carbonates etc., more rapidly.



Disadvantages or Consequences of corrosion:

1. Poor in appearance.
2. The plant may be shut down due to failure.
3. Contamination of product.
4. It affects the internal grain structure of metal.
5. It reduces the strength of the metal.
6. Safety measures, health and environmental risk when corrosion occurs, especially in manufacturing plant setting.
7. The valuable metallic properties like conductivity, malleability, ductility etc., are lost due to corrosion.

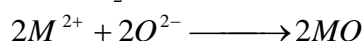
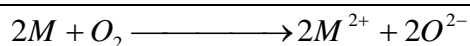
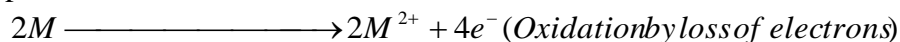
DRY OR CHEMICAL CORROSION:

This type of corrosion occurs mainly through the direct chemical action of environmental or atmospheric gases such as oxygen, halogen, hydrogen sulphide, sulphur dioxide, nitrogen, and anhydrous inorganic liquid with metal surface. There are three main types of chemical corrosion:

- (a) Oxidation corrosion
- (b) Corrosion by other gases
- (c) Liquid metal corrosion

(a) Oxidation corrosion:

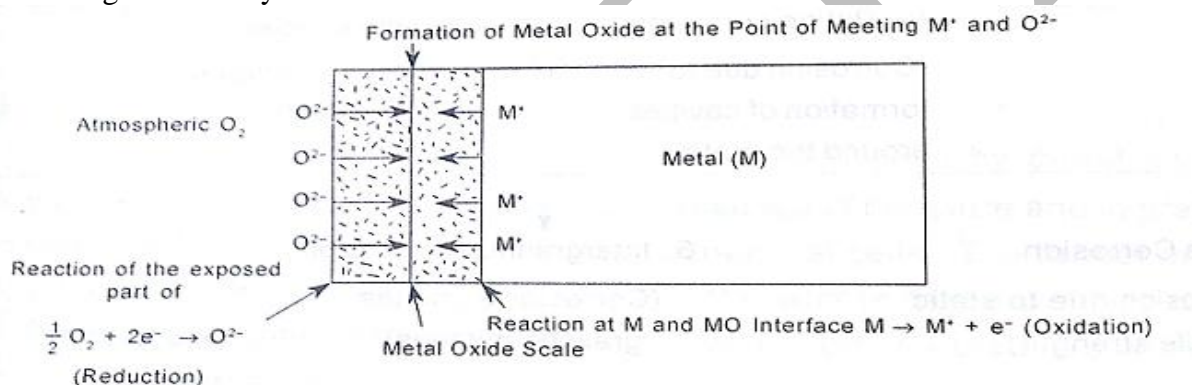
Direct attack of oxygen at high or low temperature on metals in the absence of moisture is called oxidation corrosion. Generally metals are oxidised to a smaller extent, however alkali metals (Li, Na, K, Rb, etc), and alkaline earth metals (Be, Ca, Sr, etc.), are very rapidly oxidised at lower temperature except Ag, Au and Pt all metals are oxidised at high temperature.



Mechanism of oxidation corrosion:

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

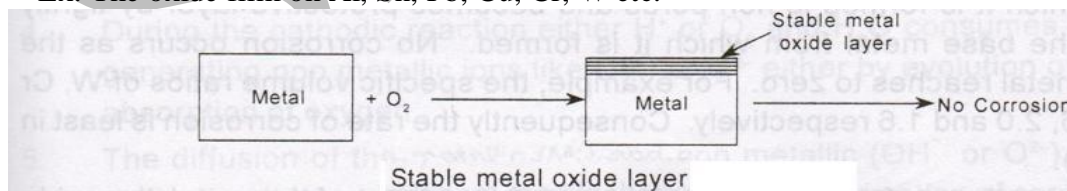
Further oxidation can continue if the metal diffuses out of the scale or the oxygen must diffuse in through the scale to the underlying metal. Of the two types of diffusions, the diffusion of the metal is rapid because the size of the metal ion is smaller than oxygen ion, hence higher mobility to metal ion.



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

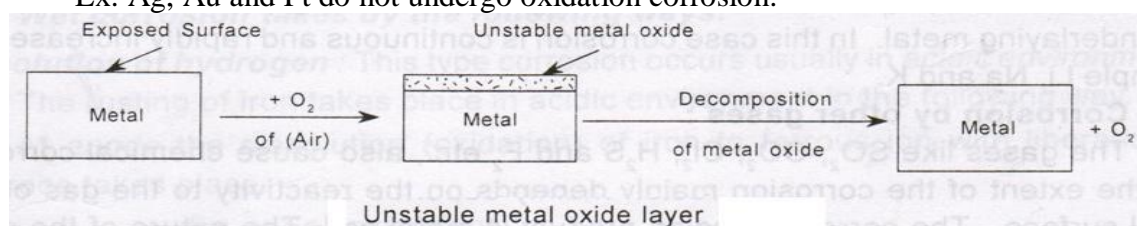
1. A stable metal oxide layer/film with fine grained structure, tightly adheres to the metal surface is impermeable to the attacking oxygen. Such film behaves as protective coating in nature, there by shielding the metal from further corrosion.

Ex: The oxide film on Al, Sn, Pb, Cu, Cr, W etc.



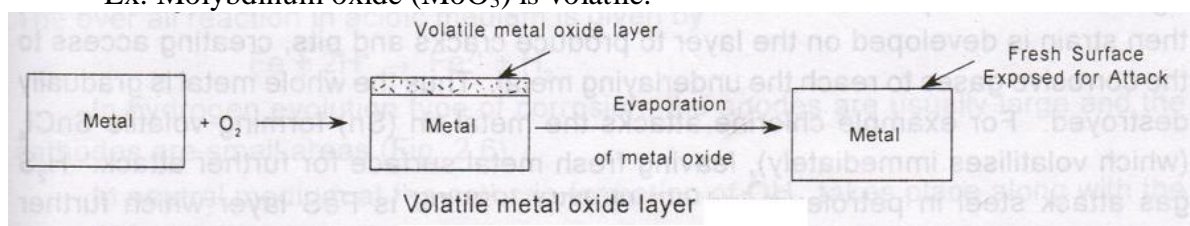
2. An unstable oxide formed on the metal surface decomposes back into the metal and oxygen. In such cases oxidation corrosion is not possible.

Ex: Ag, Au and Pt do not undergo oxidation corrosion.

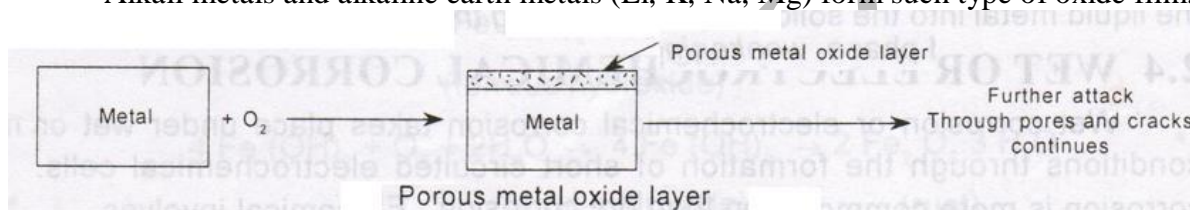


3. A volatile oxide layer formed during corrosion evaporates as soon as it is formed, leaving the metal for further attack. This causes rapid and continuous corrosion leading to excessive corrosion to occur.

Ex: Molybdenum oxide (MoO_3) is volatile.



4. A porous layer of metal oxide contains pores, cracks etc., provide access to oxygen to reach the underlying surface of the metal. As a result, the corrosion process continues to be unobstructed till the entire metal is completely converted to its metal oxide. Alkali metals and alkaline earth metals (Li, K, Na, Mg) form such type of oxide film.



Pilling-Bedworth Rule:

The rule states that “an oxide is protective or non-porous, if the volume of the oxide is at least as great as the volume of the metal from which it is formed.

$$\text{Specific volume ratio} = \frac{\text{Volume of metal oxide}}{\text{Volume of metal}}$$

The smaller the SVR, greater the oxide (formation) corrosion since the formed oxide film will be porous through which oxygen can diffuse and further corrosion takes place.

For example, alkali and alkaline earth metals formed oxides of volumes less than volume of metals, which causes continuous corrosion.

Metals like Al forms oxide, whose volume is greater than that of metals which causes non-porous layer and consequently retard corrosion.

(b) Corrosion by other gases: (SO_2 , CO_2 , H_2S , F_2 , etc.,)

The corrosion of this type depends mainly on the chemical affinity between the metal and gas involved. The intensity of attack depends on the formation of protective or non-protective films on the surface of metal.

- i. If the film is protective or non-porous (AgCl resulting from attack of Cl_2 on Ag), the extent of corrosion decreases due to formation of AgCl film which protects metal from further attack.
- ii. If the film is non-protective or porous, the metal surface is gradually destroyed, eg. Formation of volatile SnCl_4 by the attack of chlorine gas on tin.

(c) Liquid metal corrosion:

This is due to the chemical action of flowing liquid metal at high temperature on solid metal or alloy. This type of corrosion occurs in devices used for nuclear plant. The corrosion reaction is carried out either by dissolution of solid metal by liquid metal or internal penetration of liquid metal into solid metal. Both reactions lead to weakening of solid metal. Ex: Coolant (Na metal) causes Cd corrosion in nuclear reactor.

WET OR ELECTROCHEMICAL CORROSION:

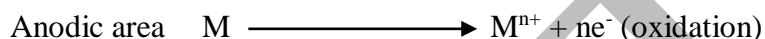
Wet corrosion or electrochemical corrosion takes place under wet or moisture conditions through the formation of short circuited electrochemical cells. Wet corrosion is more common than dry corrosion.

Electrochemical corrosion involves:

1. Cathodic and anodic areas separated by the conducting medium.
2. The oxidation of the metal liberating electrons takes place at anodic areas.
3. Depending on the nature of the corrosive environment, the electrons liberated at anode are transported to cathodic area through the metal.
4. During the cathodic reaction either H^+ or O_2 and H_2O consumes the electrons generating non-metallic ions like OH^- or O^{2-} either by evolution of hydrogen or absorption of oxygen.
5. The diffusion of the metallic (M^+) and non-metallic (OH^- or O^{2-}) ions towards each other through conducting medium results the formation of corrosion product in between the anodic and cathodic areas.

Mechanism of Wet or electrochemical corrosion:

Electrochemical corrosion involves flow of electrons between anode and cathode. The anodic reaction involves dissolution of metal as metal ions with the liberation of free electrons.

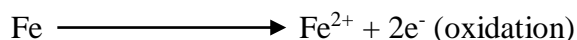
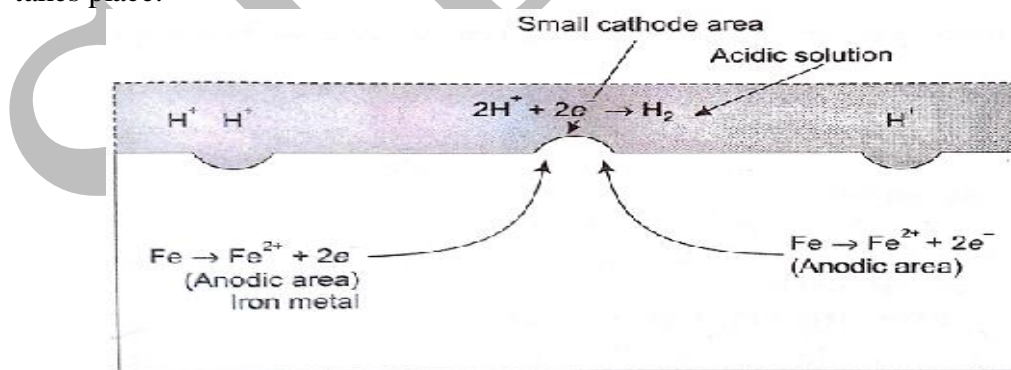


On the other side, the cathodic reaction consumes the electrons with either

- (a) Evolution of hydrogen or
- (b) Absorption of oxygen takes place based on the nature of corrosion environment.

(a) Evolution of hydrogen:

- This type of corrosion occurs usually in acidic environments.
- The rusting of iron takes place in acidic environment.
- At anode the dissolution (oxidation) of iron to ferrous iron with liberation of electrons takes place.

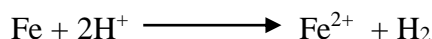


- The $2e^-$ flow from anodic area to cathodic through the metal where H^+ ions (of acidic solution) are available and eliminated as hydrogen gas.



Thus Fe^{2+} ions are liberated at anode and H_2 gas is liberated at cathode.

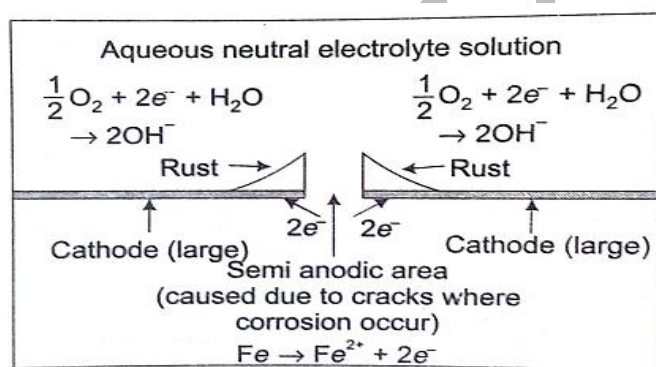
The overall reactions in acidic medium is given by



- In hydrogen evolution type of corrosion, the anodes are usually large and the cathodes are small areas.
- This type of corrosion causes “displacement of hydrogen ions from the acidic solution by metal ion”.
- All the metals above hydrogen in the electrochemical series have a tendency to get dissolved in acidic solution with simultaneous liberation of hydrogen gas.

Absorption of oxygen:

- When metals are in contact with slightly alkaline or neutral solution (H₂O) with some amount of dissolved oxygen, this type of corrosion takes place.
- Rusting of iron in presence of atmospheric oxygen with neutral aqueous electrolytic solution is a common example of this type of corrosion. The surface is usually coated with a thin film iron oxide. If a crack is developed in this iron oxide film, the anodic areas are created on the surface, while the well coated metal parts act as cathode. It shows that anodes are small area while rest of metallic part forms large area of cathode.



Mechanism of wet corrosion by O₂ absorption

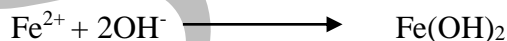
- At the anodic areas, the metal oxide as ferrous ions by liberating two electrons.



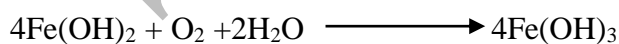
- At the cathodic areas, the electrons were accepted by water and oxygen to generate OH⁻ ions by reduction.



- The Fe²⁺ ions at anode and OH⁻ ions at the cathode react to produce ferrous hydroxide precipitate.



- If the oxygen is available in excess, ferrous hydroxide is easily oxidised to ferric hydroxide.



The above product is called yellow rust corresponds to Fe₂O₃.xH₂O.

- If the supply of oxygen is limited, the corrosion product may be black anhydrous magnetite (Fe₃O₄).

THEORIES OF CORROSION:

- Direct chemical attack:** This theory is explained on basis of dry chemical corrosion. Whenever corrosion takes place by direct chemical attack, the film of a solid corrosion product normally formed on the surface of the metal which protects the metal not to corrode further. However if corrosion product is soluble, then the metal is exposed and further corrosion takes place. For example, chlorine and iodine attack

silver, silver generating a protective film of silver halide. One of the most common ways in which metals are attacked by atmospheric oxygen. Alkali and alkaline earth metals suffer extensive oxidation even at low temperature where as at high temperature all the metals except Pt, Au, Ag are practically oxidised. The intensity of corrosion will depend on the basis of nature of oxide deposit. It is non-porous, and then the metal is protected from oxide film on the metal surface. If it is porous in nature, the oxygen diffuses, inside and further corrosion takes place. For example, Al and Cr form extremely protective oxide layer and hence these metals are normally employed for alloy formation with other more readily attacked metals to provide resistance towards oxidation.

- (b) **The acid theory:** This theory reveals that the presence of acid is essential for corrosion. Rusting of iron is well explained by this theory. Iron reacts with O₂, CO₂ and moisture of surrounding atmosphere results into a soluble ferrous carbonate which is further oxidised to basic ferric carbonate and finally ferric oxide hydrated.



- (c) **Electrochemical theory:** This theory explains indirect or wet corrosion. The modern electrochemical theory based on Nernst theory. It states that all metals have a tendency to pass into solution, when immersed in a solution of its salt, is measured in terms of its electrode potential. If a metal having a higher electrode potential comes into contact with a metal having lower electrode potential, “galvanic cell” setup and metal at higher electrode potential becomes anode and goes into the solution to a measurable extent. If the surrounding liquid is sufficiently acidic, H₂ gas will be evolved at cathode, while anodic metal dissolves. The greater the difference in potentials of cathode and anode, the greater will be the corrosion. Also, smaller will be the anode area as compared to cathode, the more severe will be the corrosion.

GALVANIC SERIES:-

Electrochemical series will give useful information regarding chemical reactivity of metals and may not be able to provide sufficient information in predicting the corrosion behaviour of metal in a particular set of environmental conditions. Passivation makes effective electrode potential of some metals more passive and acts as cathodic and exhibits noble behaviour. This behaviour is exactly opposite to that predicted by electrochemical series. For more, practical series called “Galvanic Series” have been prepared by studying the corrosion of metals and alloys in a given environment like in sea-water. This series gives real and useful information about corrosion behaviour of metals and alloys in a given environment.

Galvanic series predicts the corrosion tendency of both metals and non-metals in actual environment whereas electrochemical series predicts the displacement of metals and non-metals in electrolyte. Galvanic series, electrode potentials are measured using calomel electrode as reference electrode whereas in electrochemical series electrode potentials are measured with standard hydrogen electrode as reference electrode.

Galvanic Series (on the basis of relative oxidation potential of sea water)

1. Mg	Anodic ↑ ↓ Cathodic	14. Brass
2. Mg alloy		15. Monel
3. Zn		16. Silver solder
4. Al		17. Cu
5. Al alloy		18. Ni
6. Mild steel		19. Cr stainless steel
7. Cast Iron		20. 18-08 Stainless steel
8. High Ni cast Iron		21. 18-8 Mo steel
9. Pb-Sn solder		22. Ag
10. Pb		23. Ti
11. Sn		24. Graphite
12. Iconel		25. Au
13. Ni-Mo-Fe alloy		26. Pt

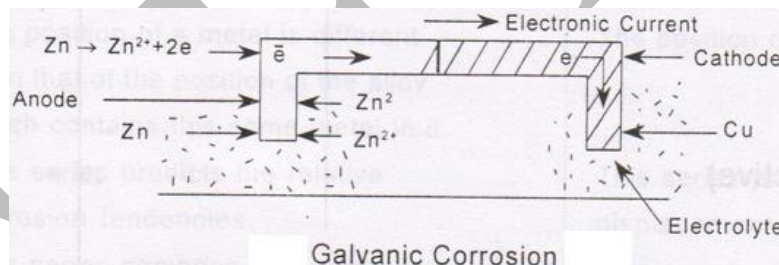
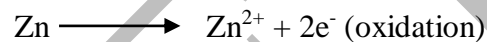
GALVANIC OR BIMETALLIC CORROSION:-

When two dissimilar metals (e.g., Zn & Cu) are electrically connected and exposed to an electrolyte, the metal higher in galvanic series undergoes corrosion. This type of corrosion is called 'galvanic corrosion'.

Ex:- Zn (higher in galvanic series) forms the anode and is attacked and gets dissolved; whereas copper (lower in galvanic series or more noble) acts as cathode. Ex:- Zn and Ag; Fe and Cu.

Mechanism:

In acidic solution, the corrosion occurs by the hydrogen evolution process; while in neutral or slightly alkaline solution, oxygen absorption occurs.



The electron-current flows from the anode metal, zinc, to the cathodic metal. Copper. Thus, it is evident that the corrosion occurs at the anodic metal; while the cathodic part is protected from attack.

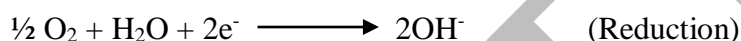
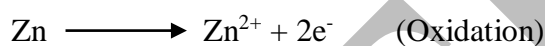
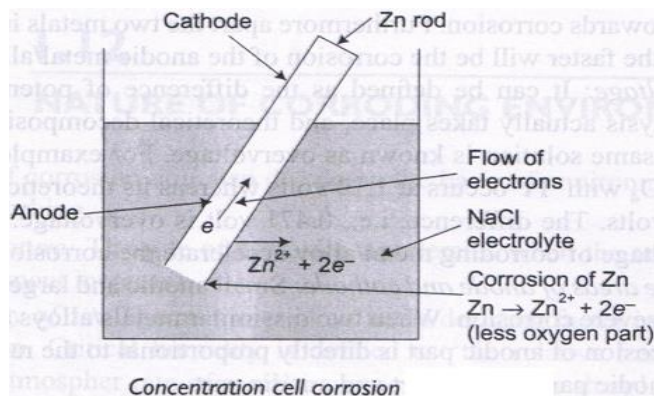
Examples:-

1. Steel screw in a brass marine hardware.
2. Lead-antimony solder around copper wire.
3. A steel propeller shaft in bronze bearing.
4. Steel pipe connected to copper plumbing.

CONCENTRATION CELL CORROSION OR DIFFERENTIAL AERATION CORROSION:-

It occurs mainly due to electrochemical attack on the metal surface exposed to an electrolyte of varying concentration or varying aerations. The most common type of concentration cell corrosion is differential aeration corrosion which occurs when one part of metal is exposed to different air concentration from other part. This causes a difference in potentials between the different areas. Poor oxygenated metallic part becomes anodic and undergoes oxidation and well oxygenated part acts as cathodic in nature.

If a 'Zn' rod is partially immersed in a diluted or neutral NaCl solution, the part above and adjacent to the water line are well aerated and hence become cathodic. Whereas parts immersed show poorly oxygenated and become anodic. So a difference of potential is created which causes flow of current between the two differential aerated areas of the same metal. Zinc will dissolve at the anode and oxygen will take up electrons at the cathodic area to form hydroxyl ions.



The following are the facts about differential aeration corrosion:

1. Less oxygenated area is the anode. Hence cracks serve as foci for corrosion.
2. Corrosion is accelerated under accumulation of dirt, scales, water drops or other contaminations. This will restrict the access of oxygen resulting in anode to promote greater accumulation. This result localises corrosion.
3. Metals exposed to aqueous media corrode under blocks of wood or glass which restrict the access of oxygen.

FACTORS INFLUENCING CORROSION:-

The rate of extent of corrosion depends on the following factors:

1. Nature of metal
2. Nature of corroding atmosphere

1. Nature of metal:-

i. Position in the galvanic series:-

When two metals or alloys are in electrical contact, in presence of an electrolyte, the metal with higher oxidation potential suffers corrosion. The metal higher in the galvanic series becomes anodic. The extent of corrosion is determination by the difference in the position of metals. The greater is difference, faster and higher is the corrosion.

ii. Over voltage:-

It is nothing but the difference of potential at which electrolysis actually takes place, and theoretical decomposition potential for the same solution is known as over voltage. Ex:- Electrolysis of 1N H₂SO₄ with 'Pt' occurs at 1.70 volts where as its theoretical potential is 1.229 volts. The difference, i.e., 0.471 volt is over voltage.

iii. Relative areas of the anodic and cathodic parts:-

When two dissimilar metals or alloys are in contact, the corrosion of the anodic part is directly proportional to the ratio of areas of the cathodic and anodic parts.

$$\text{Corrosion of the anodic part} \propto \frac{\text{Cathodic parts}}{\text{Anodic parts}}$$

For example, corrosion is more rapid, severe and highly localised if the anodic area is small. For example, a small steel pipe fitted in large copper tank.

iv. Purity of metal:-

Heterogeneity is produced if impurities are present in a metal, which form tiny electrochemical cells and anodic part gets corroded. As the extent of exposure and impurities increases, the extent of corrosion increases. For example, zinc metal containing impurities such as Pb or Fe undergoes corrosion due to the formation of local electrochemical cells.

v. Nature of surface film:-

In aerated atmosphere, practically all metals produce a thin surface film of metal oxide. The ratio of the volumes of the metal oxide formed to the metal is called specific volume ratio.

$$\text{Specific volume ratio} = \frac{\text{Volume of metal oxide}}{\text{Volume of metal}}$$

If the specific volume ratio is more, the rate of corrosion is less, because the surface of the metal is completely covered by the film, offering protection to the metal surface. For example, specific volume ratio of Ni, Cr and W are 1.6, 2.0, and 3.6 respectively. Hence, we can say that corrosion of W is least.

vi. Physical state of metal:-

The grain size, orientation of crystals, stresses etc., of the metal influence the rate of corrosion. The smaller the grain size of the metal or alloy, greater will be the rate of corrosion, because of its high solubility. The areas under stress become anodic and corrosion takes place in these areas.

vii. Passive character of metal:-

Metals like Ti, Al, Cr, Mg, Ni and Co are passive and they exhibit much higher corrosion resistance than expected from their position in the galvanic series. This is because the metal forms very thin, highly protective corrosion film, by reacting with atmospheric oxygen. If the film is broken, it compensates the film by re-exposure to oxidising conditions. Thus they produce 'self healing film'. This property is called passive character of metal. For example, the corrosion resistance of 'stainless steel' is due to passivating character of chromium present in it.

viii. Volatility of corrosion products:-

If the corrosion product volatilizes as soon as it is formed, the metal surface is exposed for further attack. This creates rapid and excessive corrosion. For example, the corrosion product of Mo as MoO₃ is volatile.

ix. Solubility of corrosion product:-

If the oxide film formed as corrosion product is soluble in corroding medium, the corrosion proceeds at a faster rate. If the corrosion product is insoluble, create physical barrier thereby suppressing further corrosion.

2. Nature of corroding atmosphere:-

i. Temperature:-

The rate of corrosion increases when the temperature of environment increases.

ii. Presence of impurities in atmosphere:-

Presence of corrosive gases such as SO₂, CO₂, H₂S, O₂ etc. in atmosphere increases acidity and high electrical conductivity, which causes severe corrosion.

iii. Presence of suspended particles in atmosphere:-

The suspended particles in atmosphere may be chemically active or inactive. If the suspended particles in nature are chemically active, [NaCl, (NH₄)₂SO₄], they absorb moisture and thus behave as a strong electrolytic medium and severe corrosion occurs. If the suspended particles in nature are chemically inactive (charcoal), they absorb both sulphur gas and moisture and slowly enhance the corrosion.

iv. Nature of ions present in the medium:-

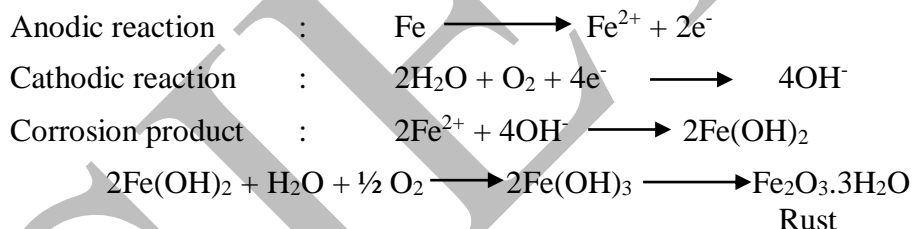
The presence of ions like silicates in the medium leads to the formation of “insoluble reaction products” like silica gel, on the metal surface which inhibit further corrosion. On the other hand, if chloride ions present in the medium, it destroys the protective film on the surface of the metal, thereby exposing the metal surface for fresh corrosion attack.

v. Conductance of the corroding medium:-

The conductance of dry sandy soils is lower than the conductance of clayey and mineralised soils. Hence the rate of corrosion is more in clayey and mineralised soils, causing severe damage to metallic structures buried.

vi. Amount of oxygen in atmosphere:-

As the percentage of oxygen in atmosphere increases, the rate of corrosion also increases due to the formation of oxygen concentration cell. The decay of metal occurs at the anodic part and the cathodic part of the metal is protected.



vii. Velocity of ions which flow in the medium:-

As the velocity of the diffusion of ions in the medium increases, the rate of corrosion increases.

viii. pH value of the medium:-

pH value of the medium has greater effect on corrosion. When pH value is lowered, the corrosion is increased.

USE OF INHIBITORS:-

A corrosion inhibitor is “a substance which when added in small quantities to the aqueous corrosive environment effectively decreases the corrosion of a metal.

Inhibitors are:-

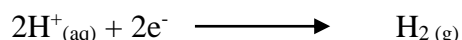
1. Anodic inhibitors:-

They are adsorbed on the metal surface, forming a protective film or barrier, thereby reducing the corrosion rate.

Ex:- Chromates, Phosphates, Tungstates or other ions of transition elements with a high oxygen content.

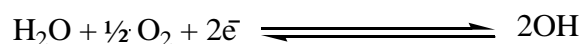
2. Cathodic inhibitors:-

- i. In acidic solutions, the main cathodic reaction is evolution of hydrogen.



Corrosion may be reduced either by slowing down the diffusion of hydrated H^+ ions to the cathode or by increasing the over voltage of hydrogen evolution. The diffusion of H^+ ions is considerably decreased by organic inhibitors (like amines, mercaptans, heterocyclic nitrogen compounds, heavy metal soaps) which are capable of being adsorbed at the metal surfaces. Antimony and arsenic oxides are used as inhibitors, because they deposit adherent film of metallic arsenic or antimony at the cathodic areas, thereby increasing considerably the hydrogen over voltage.

- i. In neutral solutions, the cathodic reaction is:



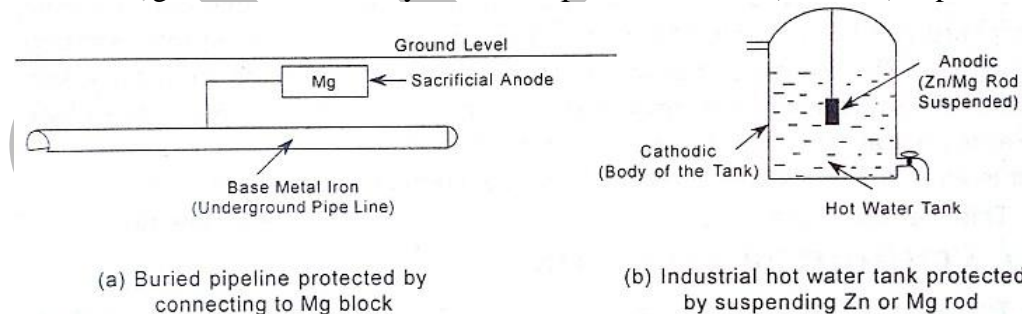
The corrosion can be controlled either by eliminating oxygen from the corroding medium or by retarding its diffusion to the cathodic areas. Elimination of oxygen is attained by adding reducing agents like Na_2SO_3 or by de-aeration. The inhibitors like Mg, Zn, Ni salts to the environments are used in the case of retarding oxygen. These react with hydroxyl ions (at the cathode) forming corresponding insoluble hydroxides, which are deposited on the cathode forming more or less impermeable self-barriers.

Cathode protection:-

The principle involved in this method is to force the metal to be protected to behave like a cathode, thereby corrosion does not occur. There are two types of cathodic protection.

(i) Sacrificial anodic protection method:-

In this method, the metallic structure (to be protected) is connected by a wire to a more anodic metal, so that all the corrosion is concentrated at this more active metal. The more active metal itself gets corroded slowly, while the parent structure (cathodic) is protected.

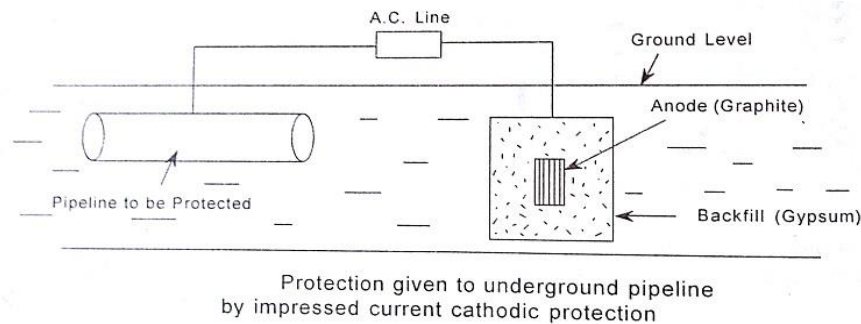


The more active metal so-employed is called “sacrificial anode”. The corroded sacrificial anode block is replaced by a fresh one, when consumed completely. Metals commonly employed as sacrificial anodes are Mg, Zn, Al and their alloys. Important applications of sacrificial anodic method include protection of buried pipelines, under cables, marine structures, ship hulls, water-tanks, piers etc.,

(ii) Impressed current cathodic protection:-

In this method, an impressed current is applied in opposite direction to nullify the corrosion current, and convert the corroding metal from anode to cathode. Usually, the impressed current is derived from a direct current (like battery or rectifier on A.C. line) with an insoluble anode (like graphite, high silica iron, scrap iron, stainless steel or platinum). Usually, a sufficient D.C. current is applied to an insoluble anode, buried in the soil (or impressed in the corroding medium), and connected to metallic structure to be protected. The

anode is, usually, in a backfill (composed of coke breeze or gypsum) so as to increase the electrical contact with the surrounding soil.



Applications:-

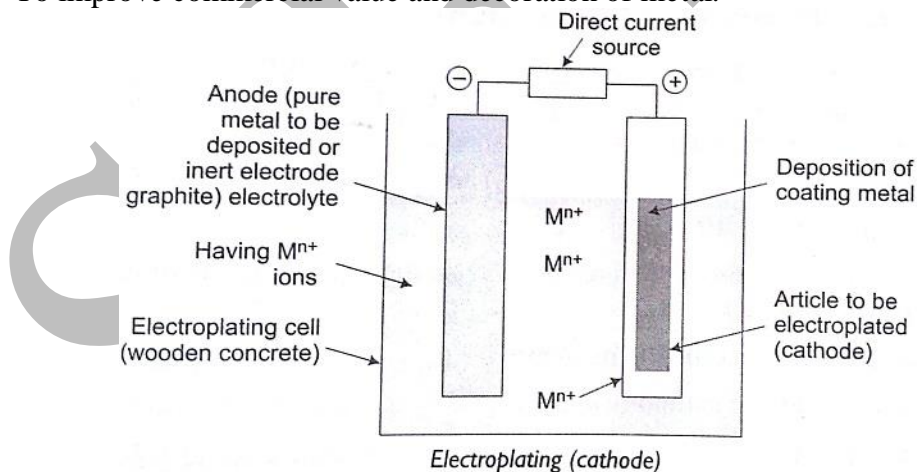
This type of cathodic protection has been applied to open water-box coolers, water-tanks, buried oil or water pipes, condensers, transmission line towers. This kind of protection technique is, particularly, useful for large structures for long-term operations.

ELECTROPLATING:-

Electroplating is the process of deposition of coating metal in the base metal by passing a direct current through an electrolytic solution which contains the soluble salt of the coating metal.

The main objectives of electroplating are:-

1. To increase the resistance of the plated metal
2. To increase the resistance to chemical attack
3. To improve physical appearance and hardness
4. To improve commercial value and decoration of metal.



- Oils, greases etc., can be removed from the surface of the metal by treating with organic solvents such as acetone, toluene, xylene, and trichloroethylene.
- Surface scales and oxides can be removed by applying HCl (Ni or Cu plating) or H₂SO₄ (Cr plating).
- The cleaned metal is then made cathode of an electrolytic cell.
- The anode is either an inert material of good electrical conductivity (Graphite) or coating metal (pure) itself.
- Electrolyte is a soluble salt solution of a metal to be coated.
- The anode and cathode are dipped in electrolytic solution kept in an electroplating cell.

- When direct current passes through, coating metal ion migrates towards cathode and gets deposited there in the form of thin layer.

ELECTROPLATING OF NICKEL:-

Nickel plating gives hard, adherent and good resistance surface. Generally nickel plating is used as an undercoat for articles which are finally to be Chromium plated.

REQUIREMENTS FOR ELECTROPLATING:-

1. Electrolytic bath:- It consists of nickel sulphate (250g/L), nickel chloride (450g/L), boric acid (30g/L).
2. pH:- Maintained at 4.0 by boric acid buffer.
3. Operating temperature:- 40-70⁰C.
4. Current density:- 20-30 mA/cm².
5. Additive agent:- Saccharin / Coumarin derivatives.
6. Cathode:- Metal article to be plated.
7. Anode:- Nickel pallets / pieces taken in a titanium mesh basket.
8. Current efficiency:- 95%.

ELECTROPLATING OF CHROMIUM:-

Chromium plating is a porous and non-adherent in which it requires that the article is first given under coat of Cu or Ni. Chromium electroplating is carried out in acidic medium by insoluble anode.

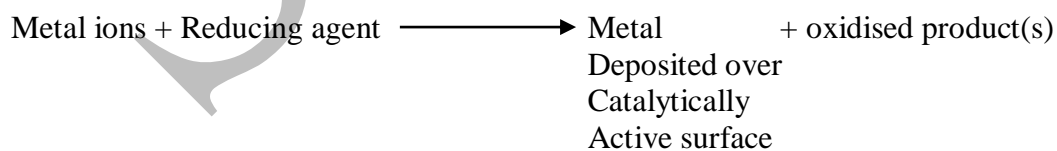
1. Electrolytic bath:- Chromic acid (H₂CrO₄) and H₂SO₄ is 100:1 by volume.
2. Operating temperature:- 40-50⁰C.
3. Current density:- 100-200 mA/cm²
4. Anode:- Lead and antimony alloy is used for getting insoluble anodes.
5. Cathode:- Article to be plated and pre-treated with organic solvents to remove oils and greases.
6. Current efficiency:- 10-12%.

Application:-

1. Corrosion resistance and decorative finish as iron objects.

ELECTROLESSPLATING:-

Electroless plating is a technique of depositing a noble (from its salt solution) on a catalytically active surface of a less noble metal by employing a suitable reducing agent without using electrical energy. The added reducing agent causes the reduction of the metallic ions to metal, which gets plated over the catalytically activated surface giving a highly uniform thin coating.



The base metal to be protected from corrosion is immersed in a bath containing sodium hypophosphate and nickel sulphate at pH 4.5-5.0 and maintains bath temperature to 100⁰C. The hypophosphate reduces nickel ion to nickel metal and finally converts into nickel phosphide. An alloy of nickel and nickel phosphide is deposited on the base metal article surface forming a strong adherent non-porous coating with high corrosion resistance.