

Corrosion

Introduction :-

Corrosion is the process of gradual deterioration of a metal from its surface due to the unwanted chemical or electro-chemical interaction of metal with its environment.

Effects of corrosion :- Effect of corrosion are briefly given below -

(A) Production related consequences :-

- (i) Loss of useful properties of metal and thus loss of efficiency.
- (ii) Decrease in the production rate, because efficiency is less and replacement of corroded equipment is time consuming.
- (iii) Increase in maintenance and production cost
- (iv) Contamination of product

(B) Health and Safety related consequences :-

- (i) unpredictable failure of machinery, sometimes lead to loss of life.
- (ii) contamination of drinking water
- (iii) Leakage of toxic liquid or gas.
- (iv) Leakage of inflammable gas from corroded pipe or instrument which can cause fire hazards.

Corrosion

For Sec. A-M

Consequences of Corrosion -

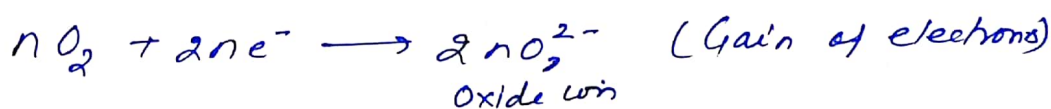
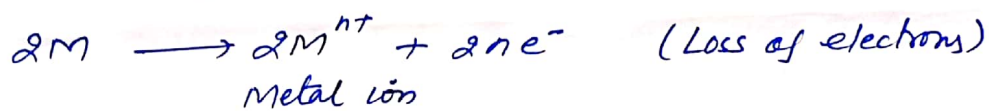
Metal and alloys that have undergone corrosion lose their look, strength, ductility and other desirable mechanical & physical properties. The decay process may be slow but the enormous losses caused due to destruction of machines, equipments and metallic products amount nearly 300 billion dollar per annum alone in U.S.A and in India yearly loss is 1.25 lakh crores ₹.

Dry OR Chemical Corrosion :-

This type of corrosion occurs mainly through the direct chemical action of environment / atmospheric gases such as oxygen, halogen, hydrogen sulphide, sulphur dioxide, nitrogen or anhydrous inorganic liquid with metal surfaces in immediate proximity. There are three main types of chemical corrosion.

- (1) Oxidation corrosion :- It is caused by the direct action of oxygen at low or high temp. on metals, usually, in the absence of metal moisture. At ordinary temperatures, metal, in general, are very slightly attacked. However, alkali metals (Li, Na, K, Rb etc) and alkali earth (Be, Ca, Sr etc) are even rapidly oxidised at low temp. At high temp, almost all metals (except Ag, Au, and Pt) are oxidised.

Rea



~~action~~ Nature of the oxide formed play an important part in oxidation corrosion process. When oxidation starts, a thin layer of oxide is formed on the metal surface and the nature this film decides the further action. If the film is

(i) Stable (ii) unstable (iii) volatile (iv) Porous.

Pilling - Bedworth Rule :- According to it "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."

Corrosion by other gases : Like SO_2 , CO_2 , Cl_2 , H_2S , F_2 etc. The extent of corrosive effect depends mainly on the chemical affinity between the metal and the gases involved.

2) Liquid metal Corrosion : It is due to chemical action of flowing

liquid metal at high temperatures on solid metal or alloy. Such corrosion occurs in devices used for nuclear power. The corrosion rxn involves either (i) dissolution of a solid metal by a liquid metal or (ii) internal penetration of the liquid metal into the solid metal. Both these modes of corrosion cause weakening of the solid metal.

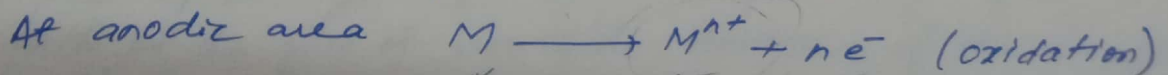
Wet OR Electrochemical Corrosion :

This type of corrosion occurs

- (i) When a conducting liquid is in contact with metal
- (ii) When two dissimilar metals or alloys are either immersed or dipped partially in a solution. This corrosion occurs due to the existence of separate 'anodic' and 'cathodic' areas/ parts, between which current flows through the conducting solution. At anodic area, oxidation reaction (i.e. liberation of free electrons) takes place, so anodic area is destroyed by either dissolving or assuming combined state (such as oxide, etc). Hence corrosion always occurs at anodic areas.

Mechanism of Wet OR Electrochemical Corrosion :-

It involves the flow of electron-current between the anodic and cathodic areas. The anodic reaction (i.e. at anodic area) involves dissolution of metal as corresponding metallic ions with the liberation of free electrons.

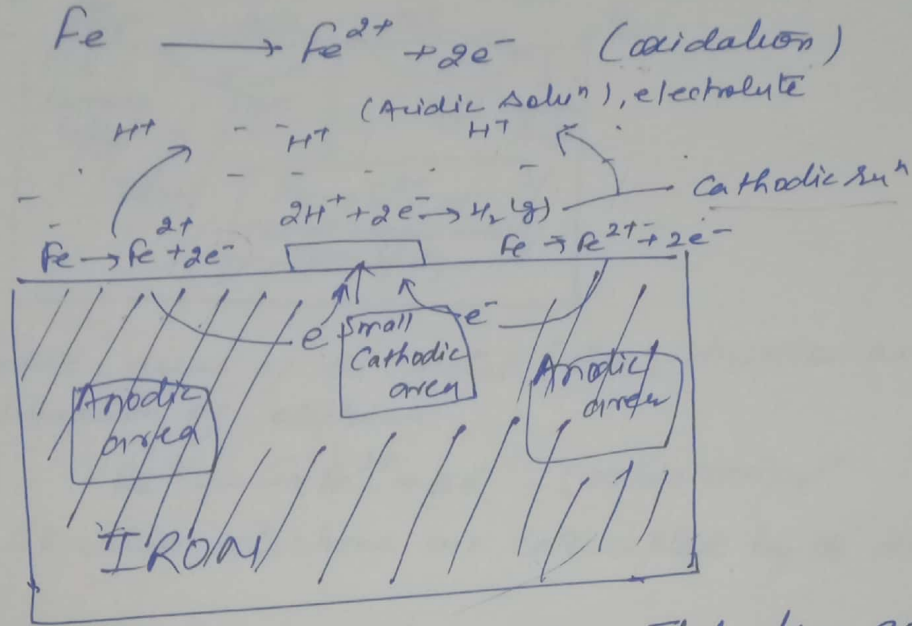


on other hand, the cathodic reaction consumes electrons with either by

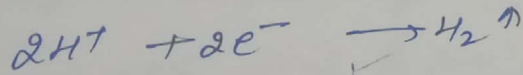
- (i) Evolution of hydrogen type : this type of corrosion occurs, usually, in acidic medium.

③

considering metal like Fe, the anodic area reaction is dissolution of iron as ferrous ions with the liberation of electrons



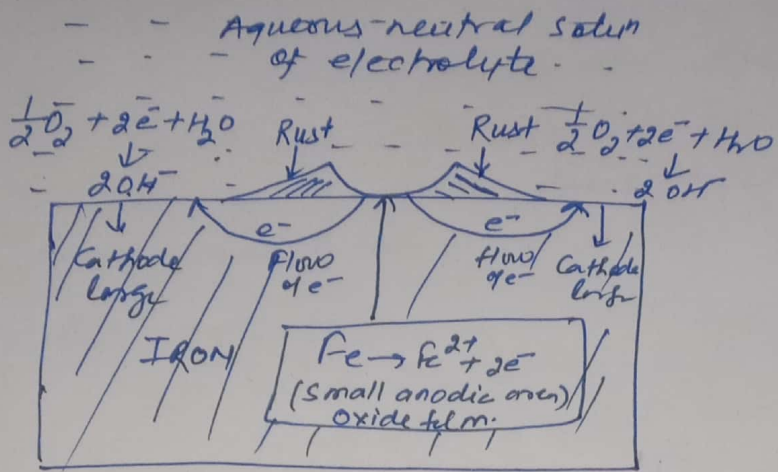
These electrons flow through the metal, from anode to Cathode, where H^+ ions (of acidic solnⁿ) are eliminated as hydrogen gas



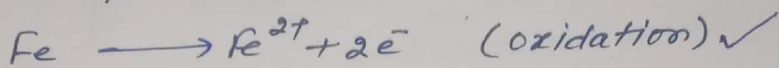
The overall reaction :- $Fe + 2H^+ \longrightarrow Fe^{2+} + H_2 \uparrow$

Thus this type of corrosion causes "displacement of hydrogen ions from the acidic solution by metal ions". Consequently, all metals above hydrogen in the electrochemical series have a tendency to get dissolved in acidic solnⁿ with simultaneous evolution of hydrogen

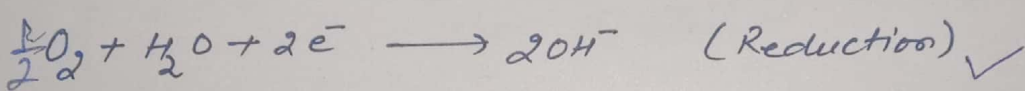
④ Absorption of Oxygen :- Rusting of iron in neutral aqueous solution of electrolyte (like Nail solnⁿ) in the presence of atmospheric oxygen is a common example of this type of corrosion. The surface of iron is usually coated with a thin film of iron oxide. However, if this iron oxide film develops some cracks, anodic areas are created on the surface while the well metal parts act as cathodes. It follows that the anodic areas are small surface parts, while nearly the rest of the surface of the metal forms large cathodes.



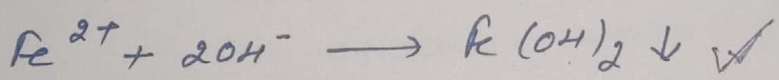
At anodic areas of the metal (Iron) dissolves as ferrous ion with liberation of electrons



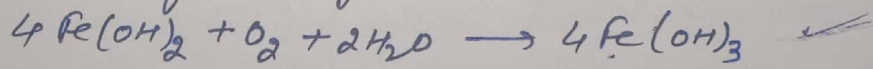
The liberated electrons are intercepted by the dissolved oxygen as:-



The Fe^{2+} ions (at anode) and OH^- ions (at Cathode) diffuse and when they meet, ferrous hydroxide is precipitated



(i) If enough oxygen is present, ferrous hydroxide is easily oxidised to ferric hydroxide



This product, called yellow rust, actually corresponds to $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$

(ii) If the supply of oxygen is limited, the corrosion product may be even black anhydrous magnetite, Fe_3O_4 . (Blue Black)

proper designing :- It is ~~desirable~~ desirable that design allows adequate cleaning and flushing of the critical parts (i.e., susceptible to dirt, deposition, etc) of the equipment. Sharp corners and recesses should be avoided, because they favour the formation of stagnant areas and accumulation of solids.

(Corrosion)
(Control) :-

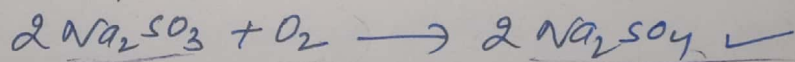
Selection of metal :- (a) using pure metal
Impurities in a metal cause heterogeneity, which decreases corrosion-resistance of the metal. Purification of metal like Al, Mg, etc. provides protective oxide films on their surfaces, when exposed to the environment.

(b) using metal alloy :- Noble, but precious metal such as platinum, and gold are corrosion-resistant. Chromium is the best suitable alloying metal for iron or steel.

modifying environment :-

(a) Deaeration :- In O_2 content type of corrosion, exclusion of O_2 from aqueous environment reduces metal corrosion.

(b) Deactivation :- It involves the addition of chemicals, capable of combining rapidly with oxygen in aqueous soln. For example, Sodium Sulphide (Na_2S)



(c) Dehumidification :- It reduces the moisture content of air to such an extent that the amount of H₂O condensed on metal is too small to cause corrosion. Alumina or silica gel, which absorb moisture on their surface.

(d) Alkaline neutralisation :- It prevents corrosion by neutralising the acidic character of corrosive environment (due to presence of H_2S , HCl , CO_2 , SO_2 etc.).

use of inhibitors !. these are -

(a) Anodic inhibitors :- (Such as Chromate, phosphate, tungstates, or other ions of transition elements with a high oxygen content) are those that stifle the corrosion rxn, occurring at the anode by forming a sparingly soluble comp. with a newly produced metal ion. ~~These~~ ^{They} are adsorbed on the metal surface, forming a protective film or barrier.

(b) Cathodic inhibitors !. The diffusion of H^+ ions is considerably decreased by organic inhibitors (like amines, mercaptans, heterocyclic nitrogen comp., substituted ureas and thioureas, heavy metal soaps), which are capable of being adsorbed at the metal surfaces.

Thial
P-SH

Protective coating :: gold, silver, Pt

(a) Electroplating :- Noble and base metal are used for electroplating on desired metal. A noble metal protects the base metal by virtue of its noble character.

(b) Hot dipping :- Hot dipping is used for producing a coating of low melting metals such as Zinc (419°C) or tin (232°C), lead, etc, on metal like steel, copper, brass etc.

→ The process of immersing the base metal in a bath of molten coating metal, covered by molten flux layer (usually $ZnCl_2$) is known as hot dipping. The flux prevents oxidation of molten coating metal.

(i) Galvanising :- Coating of Zinc on iron or steel is called galvanising.

(ii) Tinning :- Coating of tin on steels, is known as tinning.

(c) Metal spraying :- This method is utilised for huge structure like bridges in which dis mantling is not required and metal coating can be applied at any specific spot.

(iii) Metal cladding :- ~~It means that~~ "it is the process of coating of base metal by a dense, homogeneous layer of cladding materials". Cladding materials can be pure metals (which are corrosion-resisting like Ni, Pb, Ag, Pt or Cu) or alloys (like stainless steel, or alloys of Ni, Cu, or Pb). The choice depends on the environment in which corrosion resistance is required.

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Corrosion Control (Outline)

(i) Proper designing

(ii) selection of metal

(iii) Cathodic protection

(iv) Modifying environment

using pure metal

using metal alloy

Sacrificial
anode
protection

impressed
current
cathodic
protection

(v) use of inhibitors

Anodic inhibitors

Cathodic inhibitors

(vi) Application of protective coating-

Deaeration Deactivation Dehumidification

Alkaline neutralisation

Hotdipping Electroplating

metal spraying

conformal coating

cladding

Galvanising

Tinning