

Corrosion Science

- Defination:

It is the destruction or deterioration of metal through chemical or electrochemical reaction between metal & its environment.

- Consequences of corrosion:

1. Decrease in efficiency
2. Possibility of shutdown of plant
3. Possibility of accidents and hazards.
4. Maintenance cost increases.
5. Machine failure.



Types of corrosion

- I] Direct chemical or Dry or Atmospheric corrosion :-
Reaction between metal & atmospheric gases.



- II] Electrochemical or Wet or Immersed corrosion :-
Reaction between metal & electrolytic solution.



Corrosion

- It is the degradation of a material due to a reaction with its environment.

OR

- Process of Destruction of the material through chemical or electrochemical attack by its environment.
- Slow process
- Measured in weight loss per unit time.

Classification:

1. Dry or Chemical Corrosion
2. Wet or Electrochemical corrosion

1.Dry or Chemical Corrosion

- Occurs due to chemical attack of by the environment such as dry gas.
- Occurs due to high temperature and without liquid phase.

- It is of two types:

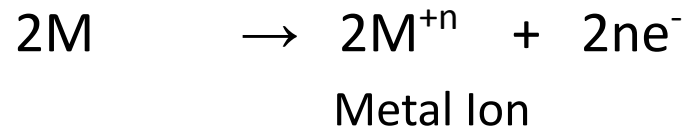
- a) Oxidation corrosion b) Corrosion by gases

(a)Oxidation Corrosion:

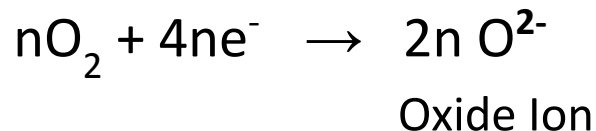
- It is due to direct attack of oxygen on metals.
- Oxygen molecules are attracted to the surface by Vander Wall Force

Mechanism:-

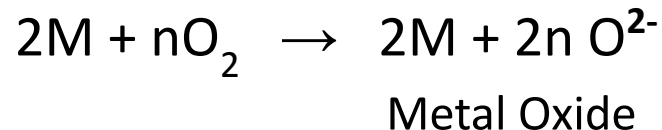
1. When temp increases the metal undergoes oxidation and losses e^-



2. Electron are gained by the oxygen molecules forms oxide ions



3. Scale of metal oxide formed



- Stable Corrosion: -Aluminium, Tin, Lead, Copper
- Non-stable corrosion:- Silver, Gold, Platinum
- Pilling – Bed Worth Ratio: Ratio of volume of oxide formed to the volume of metal consumed.

(b)Corrosion by Gases

Carbon di-oxide, Chlorine, Hydrogen Sulphide, Sulphur di-oxide, Flourine

- Depends on chemical affinity b/w metal and the gas.

Corrosion due to other gases

Other gases such as SO_2 , CO_2 , Cl_2 , H_2S , F_2 cause corrosion extent of which depends on affinity between metal and gas . E.G.

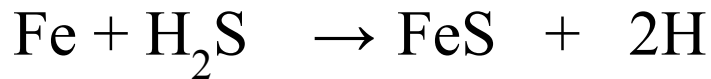
1. If the reaction product is in form of film which is **non-porous** it protects metal for ex. **Ag forms AgCl layer** when attacked by Cl_2 gas, it is non-porous and form protective film.
2. If the film formed is **non protective**, surface of metal is gradually destroyed.
Ex. **Sn forms volatile SnCl_4** which vaporizes as soon as formed causing further corrosion of metal.

ii) **Corrosion by Hydrogen:** two distinct processes occurs

a) **Hydrogen embrittlement:**

When hydrogen attacks metal at ordinary temperature, it is known as **Hydrogen Embrittlement**.

E.g. Aqueous solution of H_2S in system cause evolution of atomic Hydrogen at the surface



Atomic Hydrogen diffuses and combines to form H_2 and collect in void, pressure increases and cause blisters on metal and make metal brittle.

b) Hydrogen Attack:

High temp. H_2 diffuse into metal and atomic hydrogen forms by Thermal dissociation of mol. H_2 and combines with C, S O and N

e.g. C of steel at high temp. forms methane which causes cracking or blistering.



C) Liquid Metal Corrosion:

- Due to chemical action of flowing liquid metal on solid metal at high temp.
- Due to this either solid metal gets dissolved by liquid metal or internal penetration of liquid metal into solid metal take place.
e.g. Happens in devices used for generating nuclear power.

2. Wet or Electrochemical Corrosion

- Indirect or immersed corrosion: happens mostly under wet or moist conditions through electrochemical reaction under following conditions.

- 1) When conducting liquid is in contact with metal
- 2) When two dissimilar metals are immersed or single metal in solution of Salt, acid or base and involve transfer of electrons.

Thus corrosion occurs **due to existence of anodic and cathodic areas** between which current flows.

Here **anodic metal gets corroded** (since oxidation occurs i.e loss of electron)

Anodic M goes to M^{n+} state and surface gets corroded.

2. Wet or Electrochemical Corrosion

- Occurs when aqueous solution or liquid electrolytes are present
- Wet corrosion takes place in environments where the relative humidity exceeds 60 %.
- Wet corrosion is most efficient in waters containing salts, such as NaCl (e.g. marine conditions), due to the high conductivity of the solution.

Electrochemical series

- When metals are arranged in the order of their standard electrode potentials, the arrangement obtained is called as Electrochemical series.

- Generally electrode potential represents reduction potential.

- Metals at the top of the series, with more negative value of the Electrode potential have more tendency to pass into solution.

- Whereas metals at the bottom of the series with positive value of electrode potential have least tendency to give up their valency electrons.

Oxidized species	Reduced Species	E° in Volta
$\text{Li}^+ + \text{e}^-$	Li	-3.05
$\text{K}^+ + \text{e}^-$	K	-2.93
$\text{Ba}^{2+} + 2\text{e}^-$	Ba	-2.90
$\text{Ca}^{2+} + 2\text{e}^-$	Ca	-2.87
$\text{Na}^+ + \text{e}^-$	Na	-2.71
$\text{Mg}^{2+} + 2\text{e}^-$	Mg	-2.37
$\text{Al}^{3+} + 3\text{e}^-$	Al	-1.66
$\text{Mn}^{2+} + 2\text{e}^-$	Mn	-1.18
$2\text{H}_2\text{O} + 2\text{e}^-$	$\text{H}_2 + 2\text{OH}^-$	-0.83
$\text{Zn}^{2+} + 2\text{e}^-$	Zn	-0.76
$\text{Co}^{3+} + 3\text{e}^-$	Co	-0.74
$\text{Fe}^{3+} + 2\text{e}^-$	Fe	-0.44
$\text{Cd}^{2+} + 2\text{e}^-$	Cd	-0.40
$\text{Cr}^{3+} + 3\text{e}^-$	Cr	-0.28
$\text{Ni}^{2+} + 2\text{e}^-$	Ni	-0.25
$\text{Sn}^{2+} + 2\text{e}^-$	Sn	-0.14
$\text{Pb}^{2+} + 2\text{e}^-$	Pb	-0.13
$2\text{H}^+ + 2\text{e}^-$	H_2	0.00
$\text{Cu}^{2+} + 2\text{e}^-$	Cu	0.16
$\text{Fe}^{2+} + 2\text{e}^-$	Fe	0.34
$\text{H}^+ + \text{e}^-$	H	0.52
$\text{Fe}^{3+} + \text{e}^-$	Fe^{2+}	0.53
$\text{H}_2\text{O}_2 + 2\text{e}^-$	$2\text{H}_2\text{O}$	0.77
$\text{H}_2\text{O}_2 + \text{e}^-$	HO_2^-	0.79
$\text{H}_2\text{O}_2 + 2\text{e}^-$	H_2O	0.80
$2\text{H}_2\text{O}_2 + 2\text{e}^-$	$2\text{H}_2\text{O}$	0.86
$\text{Br}_2 + 2\text{e}^-$	2Br^-	0.91
$\text{Cl}_2 + 2\text{e}^-$	2Cl^-	1.08
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^-$	$2\text{H}_2\text{O}$	1.23
$\text{Au}^{3+} + 3\text{e}^-$	Au	1.50
$\text{Co}^{3+} + \text{e}^-$	Co^{2+}	1.82
$\text{F}_2 + 2\text{e}^-$	2F^-	2.87

Electrochemical Series
Standard Reduction Potentials (298K)

Galvani c Series

- Standard electrode potential measurement requires some specific chemical conditions i.e conc, temp, electrodes must be clean, nature of metal oxide layer.
- It is difficult to measure exact electrode potential under such Conditions, so correct value of electrode potential can not be Obtained.
- To overcome this difficulty new series Galvanic series introduced where calomel electrode can be used as a reference electrode & sea water can be used as an electrolyte.



Electrochemical series

- 1. Series of metals and non metals.
- 2. The position of a metal in the series is permanently fixed.
- 3. It predicts relative displacement tendencies.
- 4. Electrode potential measured by Dipping pure metal in its ion solution.
- 5. Electrode potential measured Using SHE.

Galvanic series

- 1. Series of metals and alloys
- 2. Position of metal and alloy is different.
- 3. It predicts relative corrosion tendencies.
- 4. Measured in common electrolyte like sea water without any oxide film.
- 5. It is measured using std. Calomel electrode

▪ **Metal** higher in series act as anode. **Less** active metal act as cathode
Oxidation occurs at anode and corroded. **Reduction** occurs at cathode and protected. **More** the diff. Between the two, faster the corrosion of anodic metal.

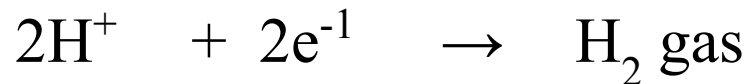
Mechanism of Wet or Electrochemical corrosion

Anodic reaction: $M \rightarrow M^{+n} + ne^{-1}$

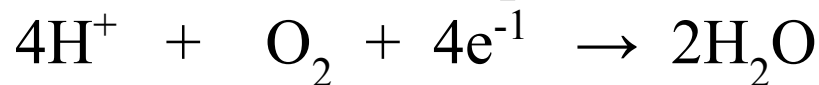
Cathodic reaction:

1. In acidic medium in absence of oxygen

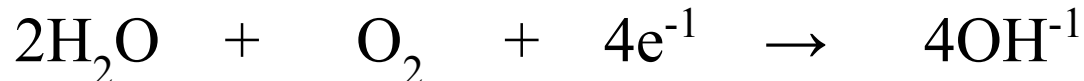
H⁺ combines with electrons to form hydrogen gas



2. In acidic medium in presence of oxygen



3. In neutral or alkaline medium in presence of oxygen

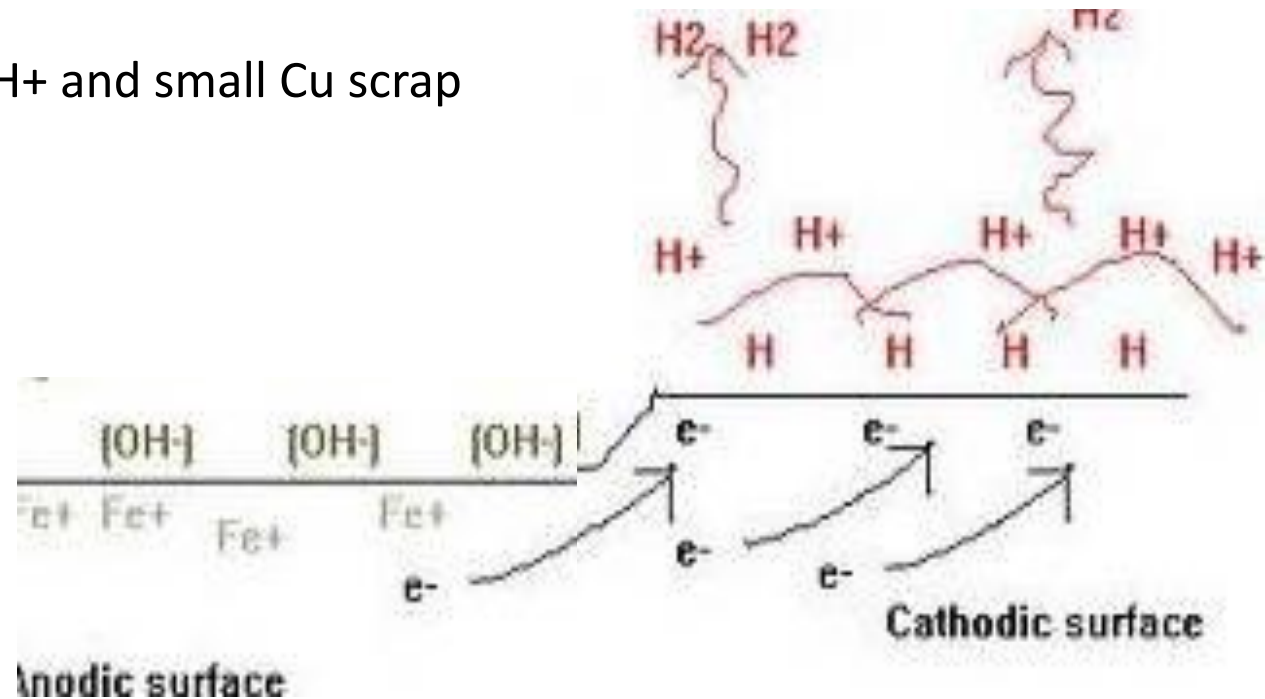


There are two mechanism

- 1) Hydrogen evolution mechanism
- 2) Oxygen absorption mechanism

1)Hydrogen evolution mechanism (In absence of Oxygen)

E.g. A steel tank containing H^+ and small Cu scrap

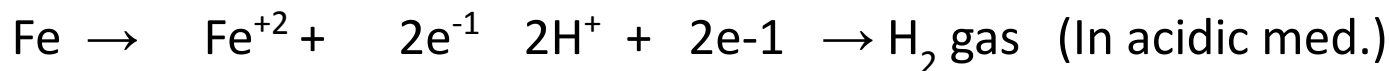


Anode= steel tank

Cathode = Cu

At steel tank (anode)

At cathode



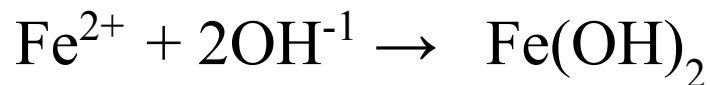
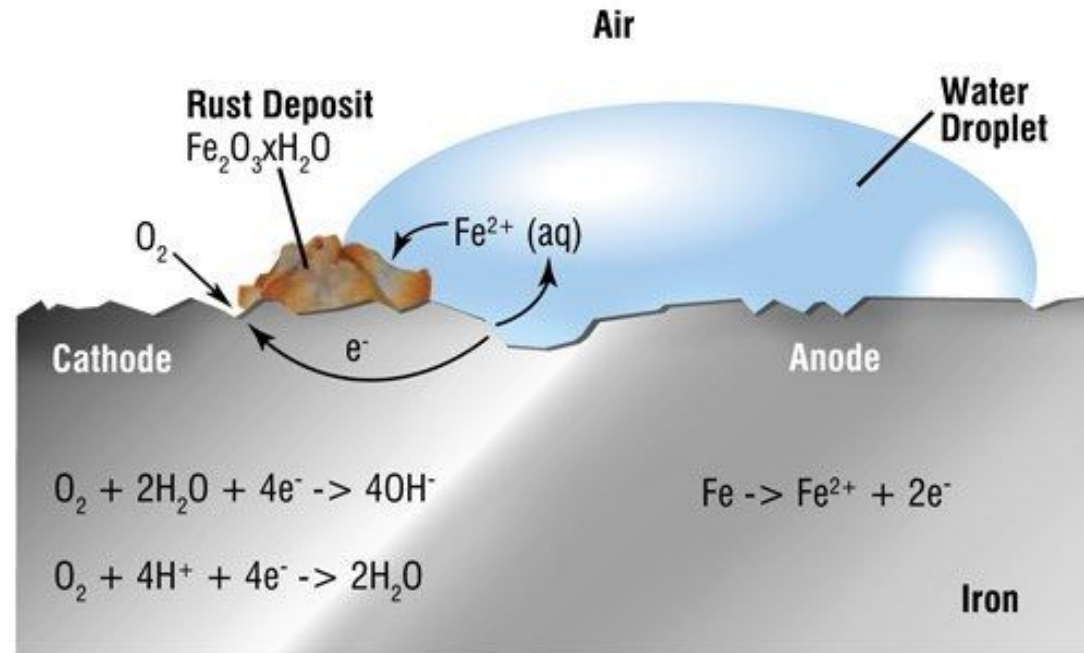
In hydrogen evolution mech., cathode has small area as compared to anode.

ii) Oxygen absorption mechanism:

When electrolyte is neutral or alkaline. Following e.g is steel plate with crack in oxide Film and water drop as electrolyte.

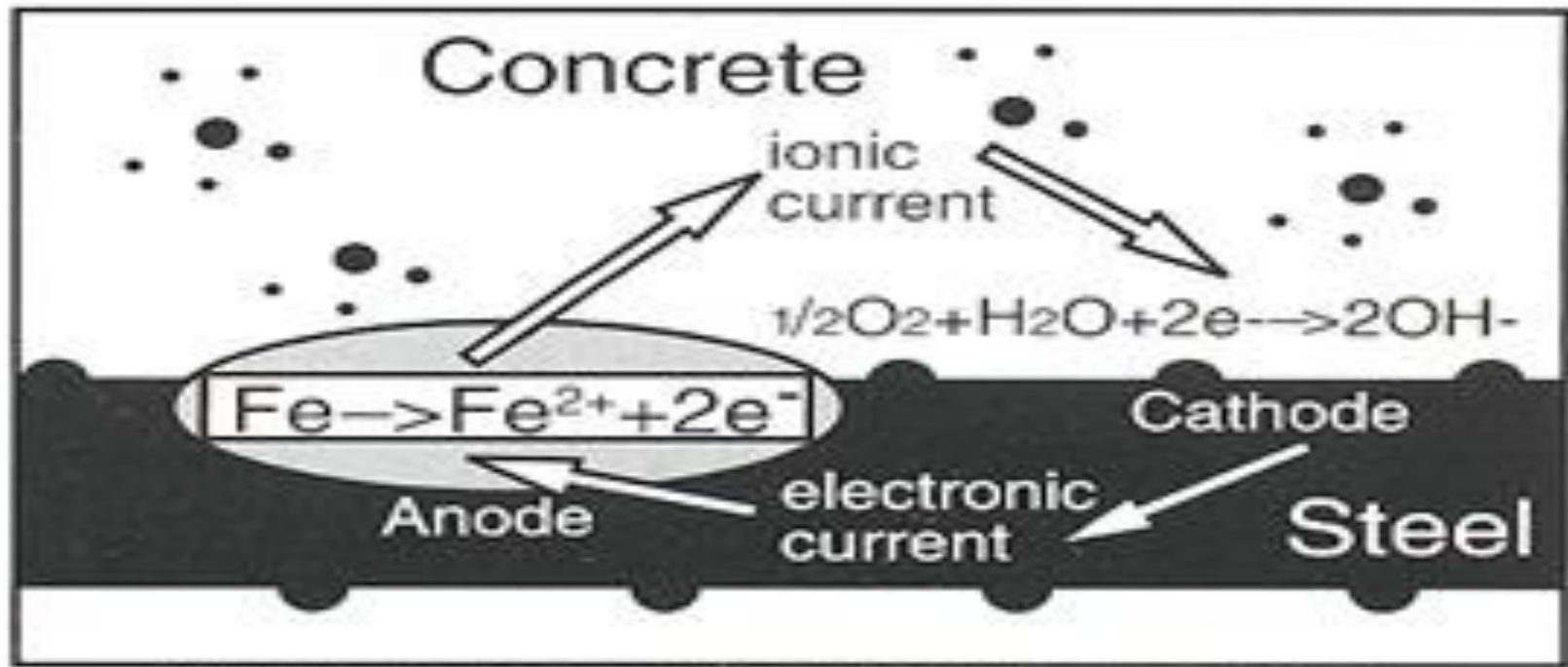
Crack as anode

oxide film as cathode



Increase in O_2 content increase corrosion. In oxygen absorption mechanism, cathode has more area than anode

Mechanism Of Electrochemical Corrosion



Anodic Reaction:

Dissolution of metal takes place.

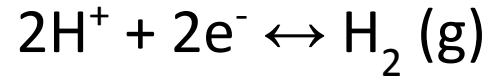
- As result metal ions are formed with the liberation of free electrons.



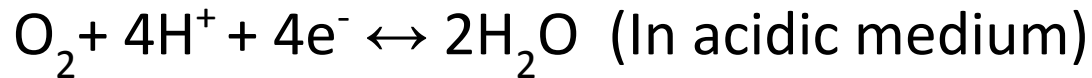
Metal Ion

Cathodic Reaction

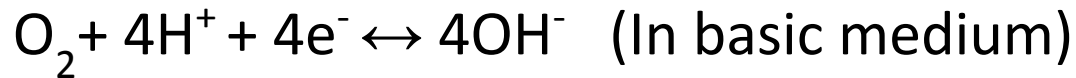
(i) Hydrogen Evolution :- Occurs usually in acidic medium



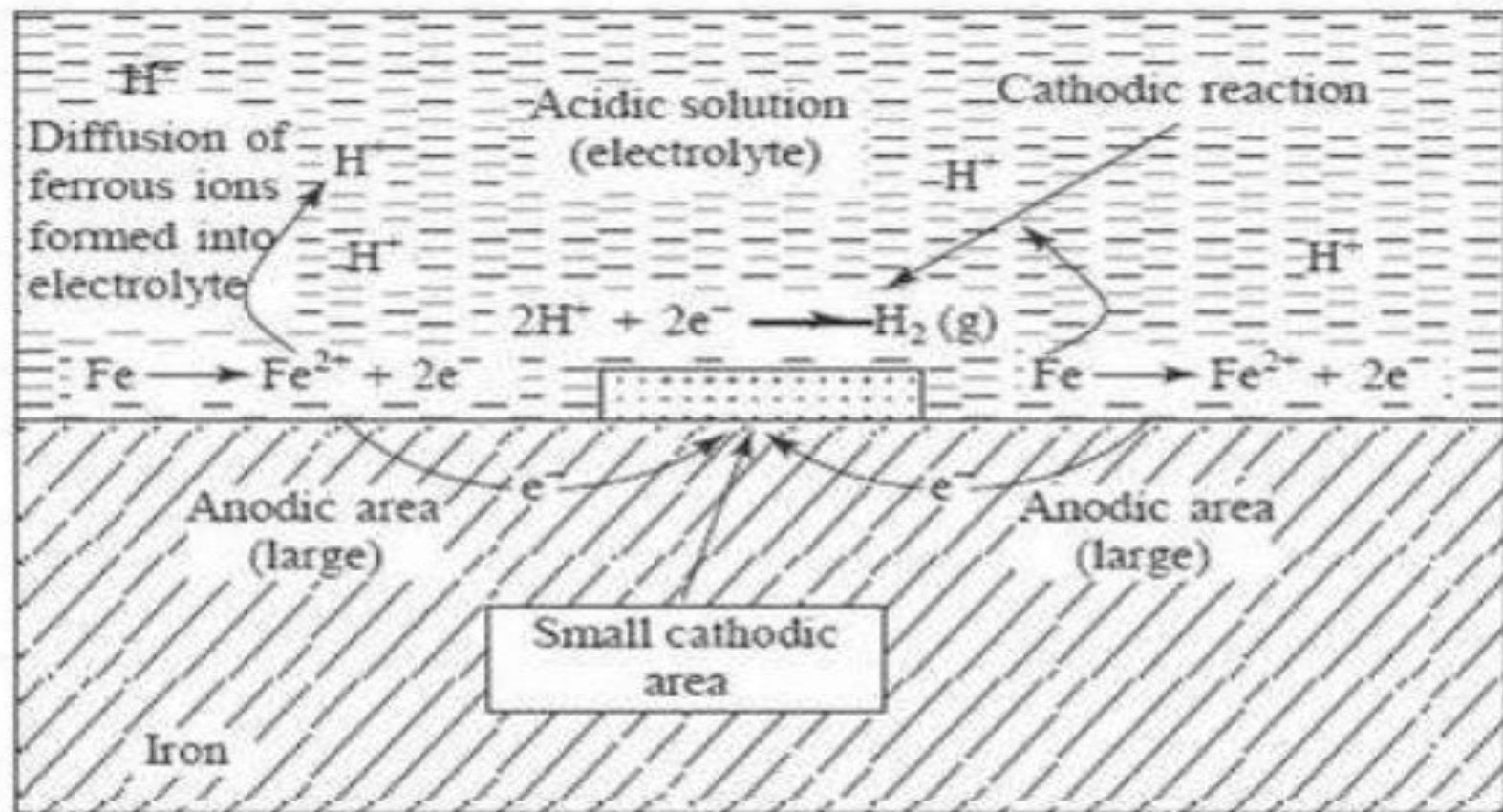
(ii) Oxygen Absorption :- occurs when solution is aerated sufficiently.



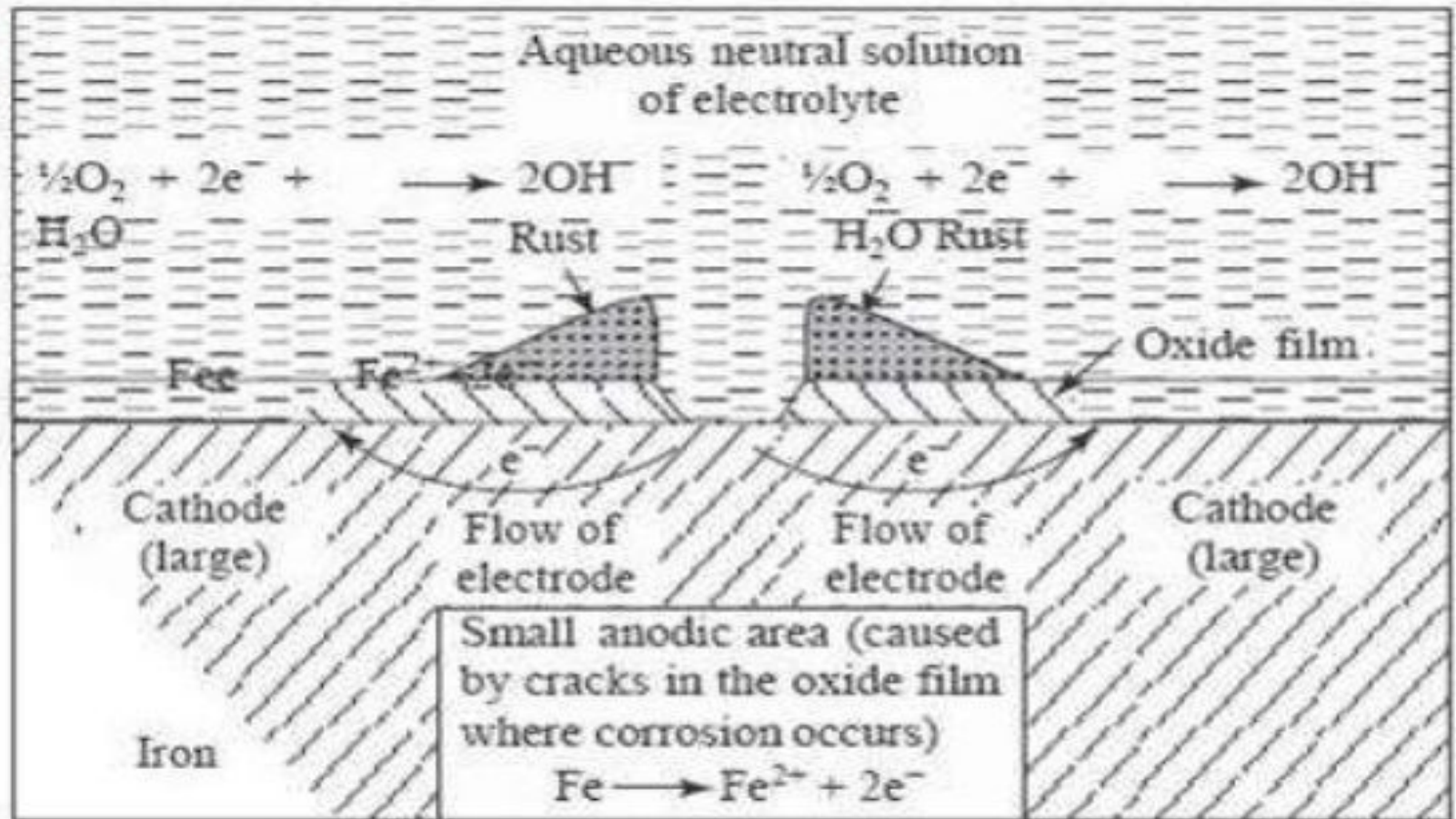
lii) In neutral or alkaline medium :- Dissolved O₂ combines with electrons & hydroxyl ions.



Mechanism of wet corrosion by hydrogen evolution

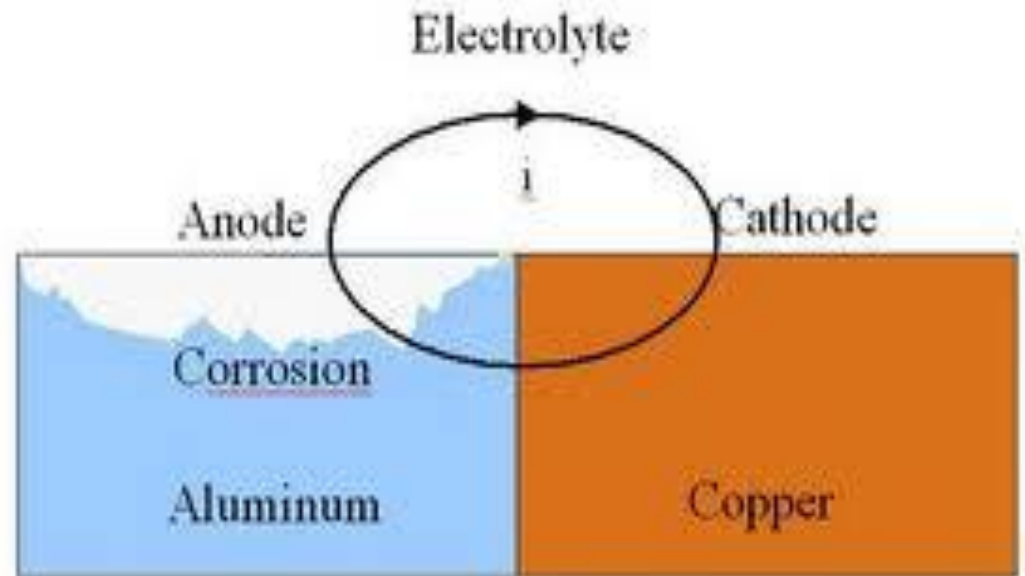
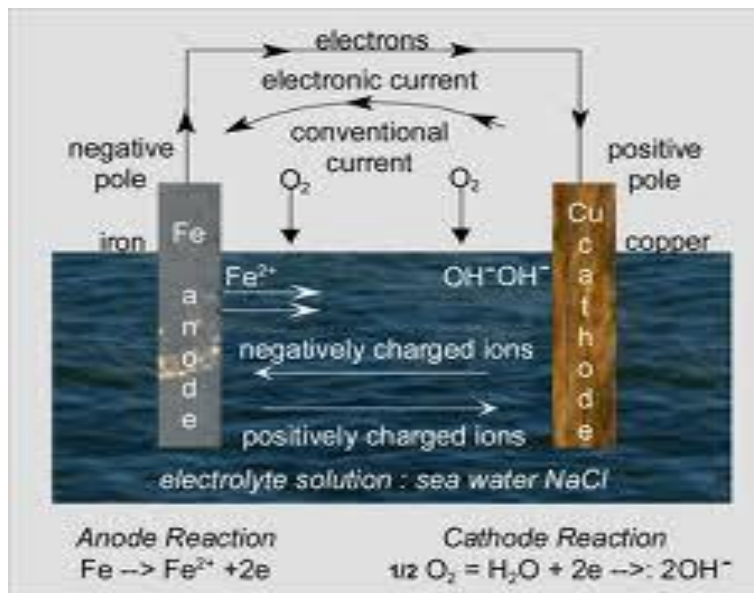


Mechanism of wet corrosion by oxygen absorption



Forms of wet Corrosion:

Galvanic Corrosion:- When two different metals are present in contact with each other in conducting medium e.g. Electrolyte, the metal higher in electrochemical series undergoes corrosion.



2. Concentration cell corrosion: This type of corrosion occurs when a single piece of Metal is exposed to an electrolyte of varying concentration or aeration.

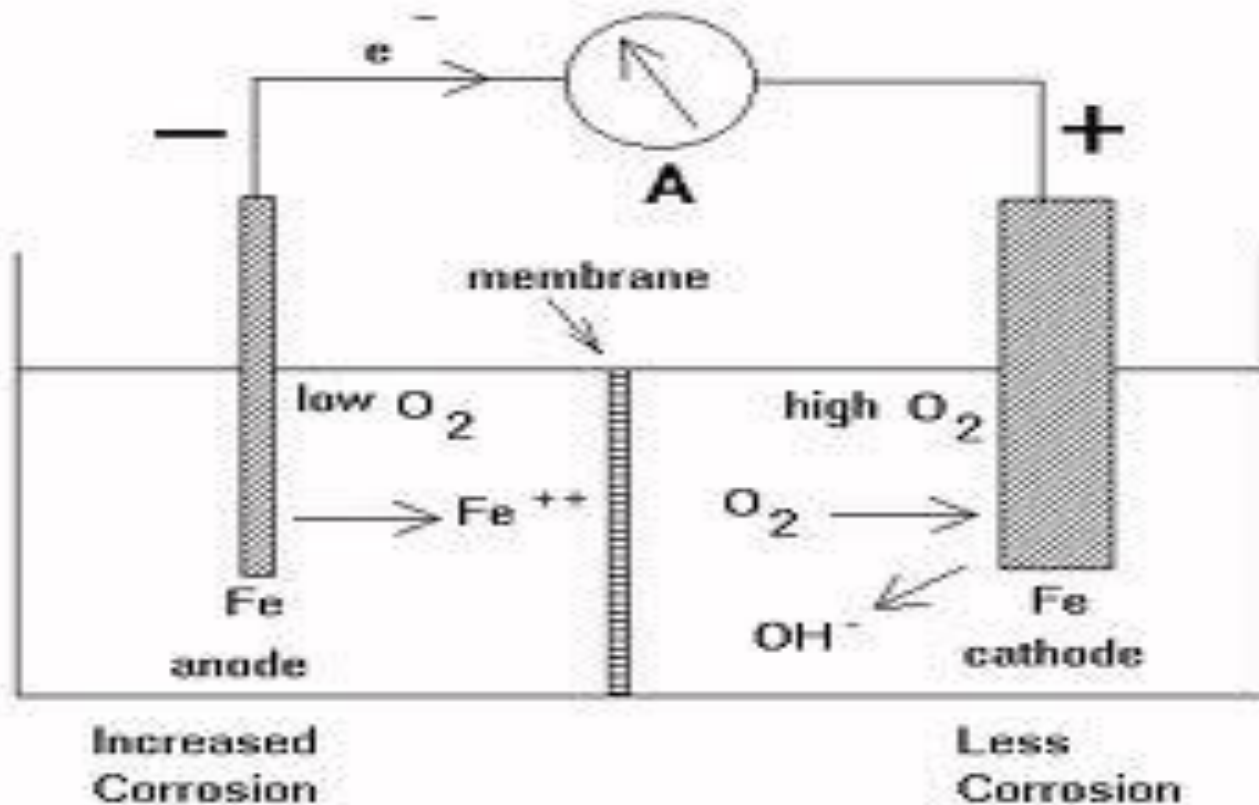
Two types:

- 1) Metal – ion concentration cell
- 2) Oxygen concentration cell

1) Metal – ion concentration cell corrosion:

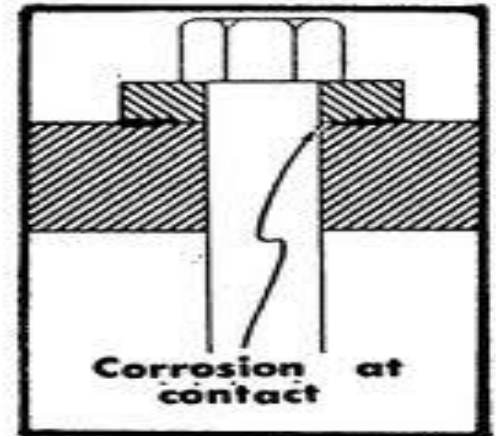
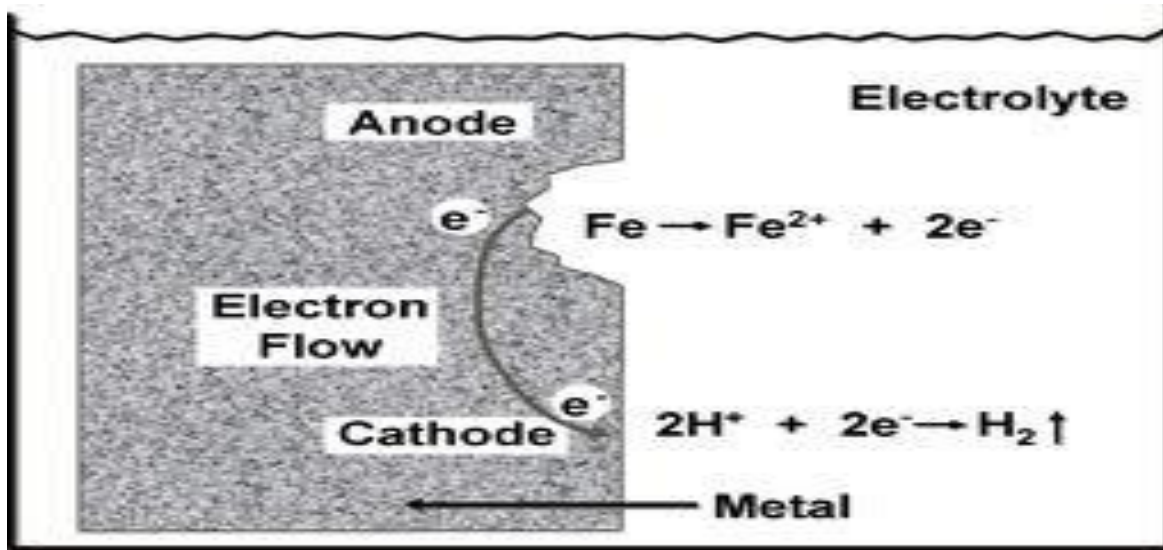
When two electrodes of the same metal are immersed into two solutions of different concentrations of the same electrolyte and are joined externally, they form a **Metal-ion concentration Cell**.

2. Oxygen Concentration Cell Corrosion: When different parts of metal are exposed to different aeration, the potential difference is developed. **Less Aerated metal part** behaves as **anode** and **more aerated part** as **cathode**.



(b) Concentration Cell Corrosion:-

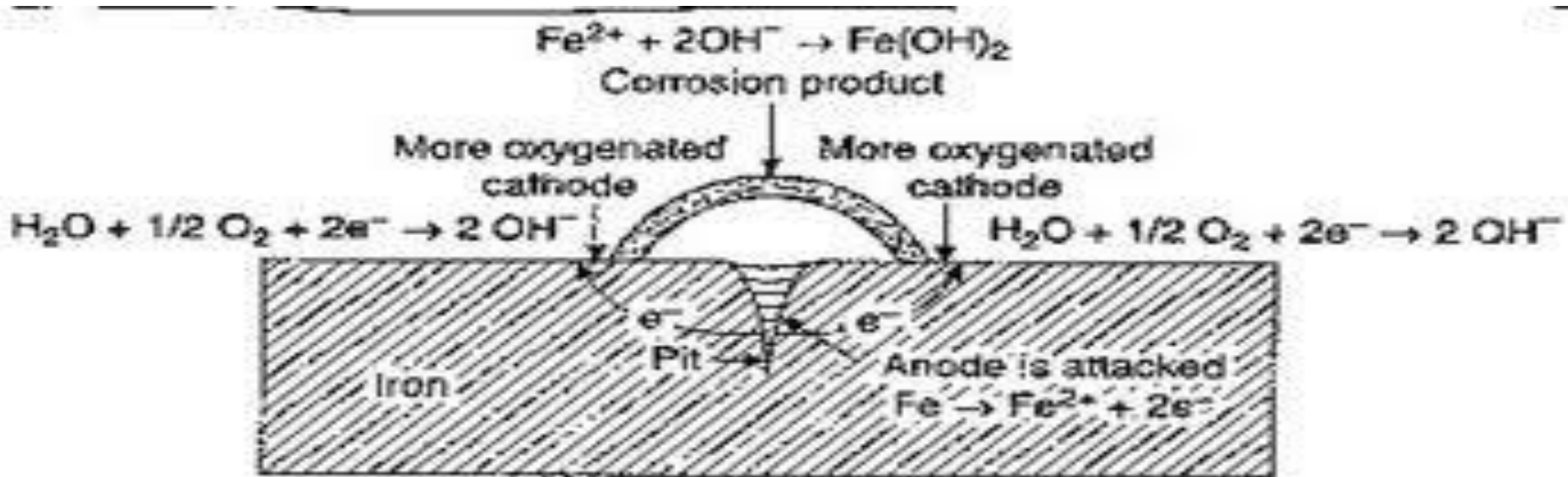
- Same as Galvanic corrosion
- Occurs when two different metals are exposed to different air conc.



Other types of corrosion

1) Pitting Corrosion:-

- Formed as a result of pit and cavities
- localized, fast attack resulting in cavity around which metal is not affected.
- It occurs due to crack in protective cover of metal leading to Small anodic and large cathodic area.



2) Stress Corrosion:

- Occurs in the presence of tensile stress and corrosive environment
- E.g. brass get corrode in traces of ammonia.

Due to uneven stress like, cold working, quenching, bending
Pressure or heat.

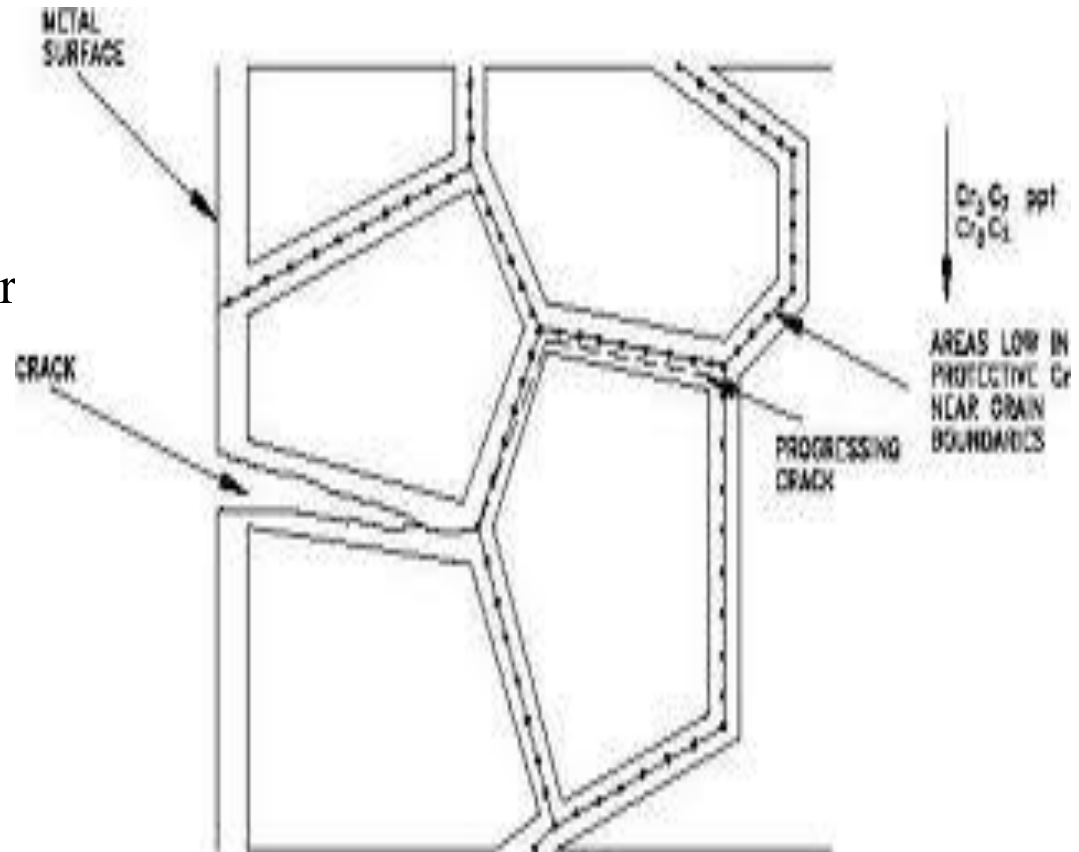
Areas under stress act as **anode**, other areas act as **cathode** in presence of
Corrosive environment.



3) Inter-granular Corrosion:

- ✓ Occurs in granular metals and homogenous alloys.
Occurs along grain boundaries which contain material which has more anodic nature than grain centre in corroding liquid. The centre is untouched and ppt of corrosion happen at boundary only.

- ✓ Welding of steel (Alloy of Fe, C, Cr)
CrC ppt out at grain boundary.
Cr depleted area become anodic w.r.t. Inside of grain solid



4. Erosion Corrosion:

This happens when gases or vapours or liquid strike side-walls with high velocity. The effect of abrading action of turbulent flow and mechanical rubbing of particles with metal surface which leads to formation of differential cells. The localized corrosion at anode is then set up.

5. Water Line corrosion:

In a tank with stagnant water, Oxygen concentration is greater above the water surface than oxygen under the surface.

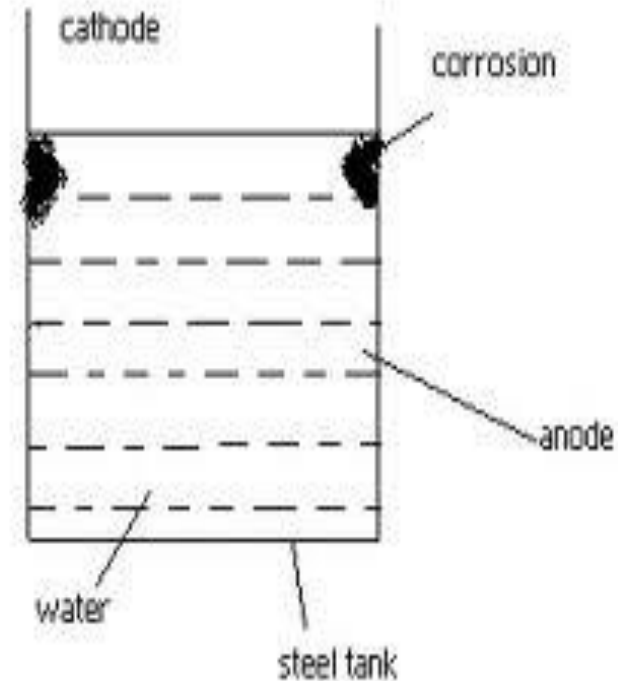
This leads to Oxygen concentration cells.

In this cell, metal **above** water line is **cathode**

and metal **below** water line is **anode**

corrosion occurs at this are i.e. below water level.

Water Line Corrosion



6. Soil corrosion:

Moisture, bacteria, micro-organisms and electrolyte present in soil are responsible for soil corrosion.

Differential aeration is also the other factor responsible for soil corrosion.

It happens for pipe lines and cables passing from one type of soil to another.

Lead pipe passing from clay (less aerated) to sand (more aerated)

Which portion of pipeline will corrode.?

The pipe which is in clay will corrode.

In water-logged soil, the aeration is less and more microbes

Which corrode the metal.

Factors affecting corrosion

Rate of corrosion depends on

.Nature of metal

.Nature of environment

.Nature of metal

)Oxidation potential: Depends on position of metal in electrochemical series and Galvanic series, more higher metal placed more anodic and suffers corrosion.

More the Potential difference between anode and cathode, more and fast will be corrosion .

b) Over-voltage: The voltage or potential at which H_2 gas liberated at cathode in Hydrogen evolution mechanism is called decomposition potential.

The **difference between theoretical and actual potential is called over-voltage**

Higher the over-voltage, slower and lesser is the corrosion.

Eg. Pb, Sn, Cd do not corrode in acidic solution due to higher voltage.

Zn (over-voltage = 0.7V) slow corroding in 1N H_2SO_4 can be made to corrode fast by adding $CuSO_4$ (over-voltage = 0.33V) and $PtCl_2$ (over-voltage = 0.2V)

c) Relative areas of anode and cathode: when two dissimilar Metals are in contact, corrosion of anodic part is related to ratio of areas of cathodic part and anodic part.

If **cathodic area is higher** than anode, corrosion more **rapid and Severe**. The great demand for electrons by large cathodic area met by smaller anode only by undergoing more corrosion.

d) Purity of metal:

As pure metal have higher corrosion resistance as compared to Impure metal.

Impurities (Pb, Fe) form galvanic cell and anodic (Zn) get corroded.

Hence traces of impurities cause very rapid corrosion.

e) Nature of corrosion product: in electrochemical corrosion if corrosion product is soluble in corroding medium, fast corrosion occurs. If it is volatile, cause rapid and continuous corrosion.

f) Physical state of the metal: rate of corrosion affected by grain size, Orientation of crystals, stress etc.

Smaller the grain-size of metal = greater will be its corrosion

Under stress = even pure metal gets corroded. Stressed area anodic
And unstressed is cathodic in nature.

g) Nature of the oxide film: Ratio of volume of oxide formed to volume of metal is called specific volume ratio, decides extent of corrosion. For Li, Na, K, Ca, Mg **specific volume is less**, therefore nature of film is porous and less protective and **so more corrosion**.

For Al, Cr, Ni **greater specific volume** hence film is nonporous, protective and **not much corrosion**.

Pilling-Bedworth Rule = volume of oxide/volume of metal

2. Nature of the Environment

a) Temperature: Corrosion increase with increase in temperature, since the rate of diffusion and chemical reaction increases with temperature. Thus corrosion enhances with the rise in environment temperature.

b) Humidity: Corrosion is very fast in moist condition than dry atms. Because moisture act as solvent for gases like O_2 , CO_2 etc.

- This produce electrolyte which set galvanic Cell or corrosion cell.
- Even in absence of gases, water corrodes Mg, Al, Zn, Cr, Fe.

c) pH of the medium: generally metals corrode fast under acidic condition than neutral or alkaline condition.
Hence corrosion tendency can be reduced by elevating the pH.
E.G. Zn corrodes slow at $\text{pH} > 11$ in absence of O_2 .

d) Nature of ions present : Silicate anion form insoluble products which form scale and inhibit further corrosion.

If Cl^- present, it destroy protective film, expose metal surface and causes fresh rapid corrosion.

e) Conductance of corroding medium:

In case of corrosion of underground or Submerged structure, the conductance of medium i.e. Soil affects the rate of corrosion as corrosion current depends on it.

- ✓ Clay and mineralized soil is more conducting thus causing more corrosion than sandy soil.

f) Formation of Oxygen concentration cell: If two different portions of the same metal are exposed to different aeration and get different amount of oxygen, then Oxygen Concentration cell is formed.

Such differential aeration leads to corrosion of less oxygenated part, it acts as anode.

Prevention of metal from corrosion

1. Modification of environment
2. Application of inhibitors
3. Cathodic and anodic protection
4. Application of protective coatings
5. Proper designing and material selection

Corrosion Control:

1. Selection of metal and alloy:

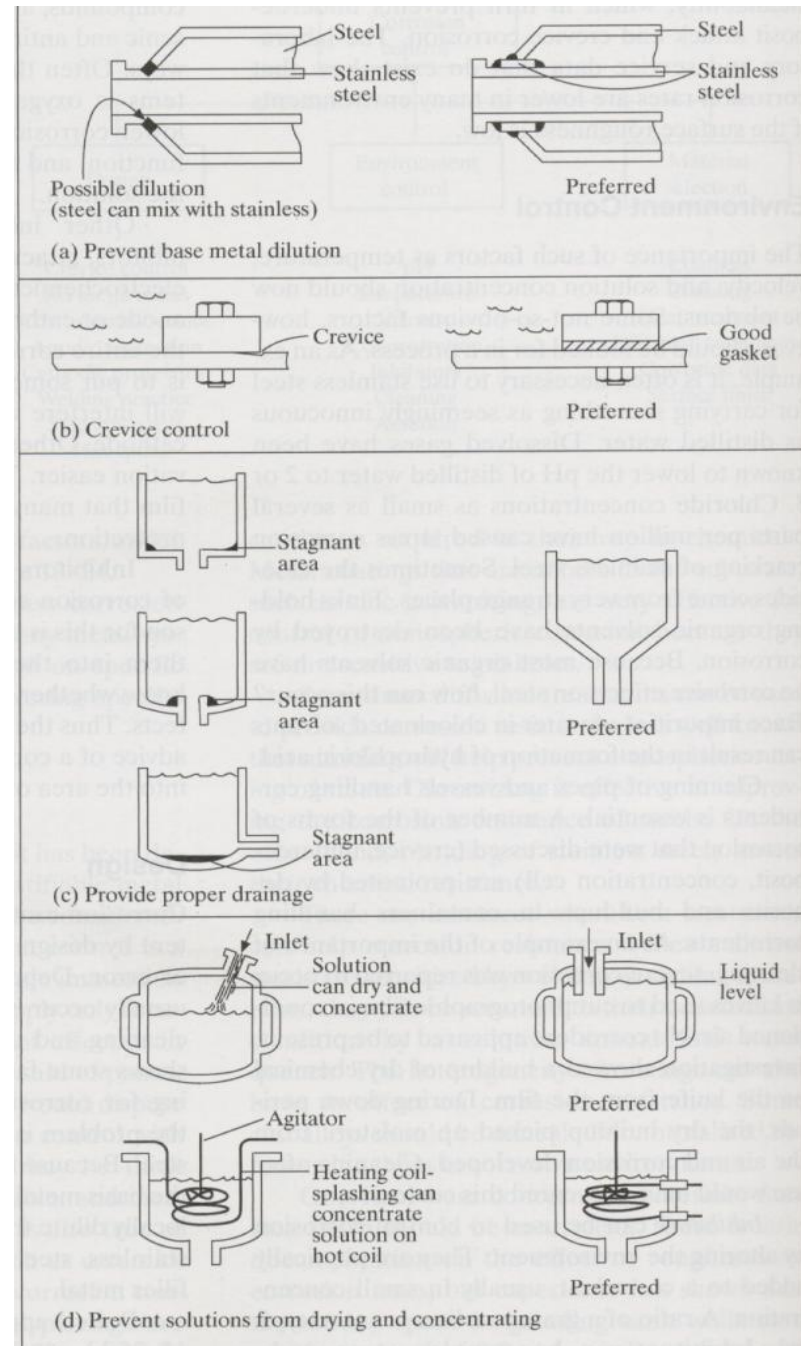
- Using pure and noble metals
- Practically not possible because of low strength of pure metal
- Use of metal alloys which are homogeneous

2. Proper design of metal:

- Use of single metal is preferred
- Use of two dissimilar metals are used
- Adequate ventilation and drainage
- Welded joints should be used
- Avoid cervices b/w adjacent parts
- Bend should be smooth
- Bimetallic contacts should be avoided
- Paint cathodic portion

Prevent uneven stress

- Prevention from moisture



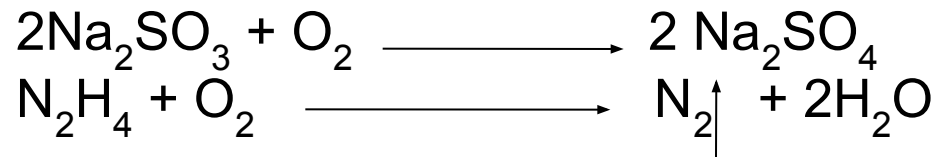
Modification of Environment

(v) **Modifying the environment:** The rate of corrosion also depends on corroding environment. The corrosive nature of environment can be reduced by,

(a) **Deaeration:** Driving out dissolved oxygen by adjustment of temperature with mechanical agitation.

(b) **Deactivation:** This involves addition of chemicals capable of combining with oxygen in aqueous solution.

e.g.,



(c) **Dehumidification:** Reduction of moisture content of air belongs to this step. e.g., **alumina or silica gel** can absorb moisture which are used in air-conditioning shop.

d) **Alkaline neutralization:-** alkaline neutralizers are used to prevent the corrosive effect of environment by neutralizing acidic character due to atmospheric gases like H₂S, SO₂, HCl etc

Applications of inhibitors

Anodic Inhibitors :- They suppress anodic reaction or metal dissolution. Oxidizing substances like **chromates, phosphates, nitrates** etc are used as inhibitors for protection of iron, steel.

Oxygen works as the anodic inhibitor which & forms a protective film on metal surface, which reduces corrosion rate.

Cathodic Inhibitor:- They prevent evolution of hydrogen.

a) In **acidic** solution organic inhibitors like **amines, mercaptants**, are added which get adsorbed on cathodic metal surface preventing diffusion of hydrogen by increasing overvoltage.

b) In **neutral** solution, inhibitors like **Mg, Zn, Ni salts** are used. They react with hydroxyl ions forming insoluble hydroxide which are deposited on cathode & acts as a barrier.

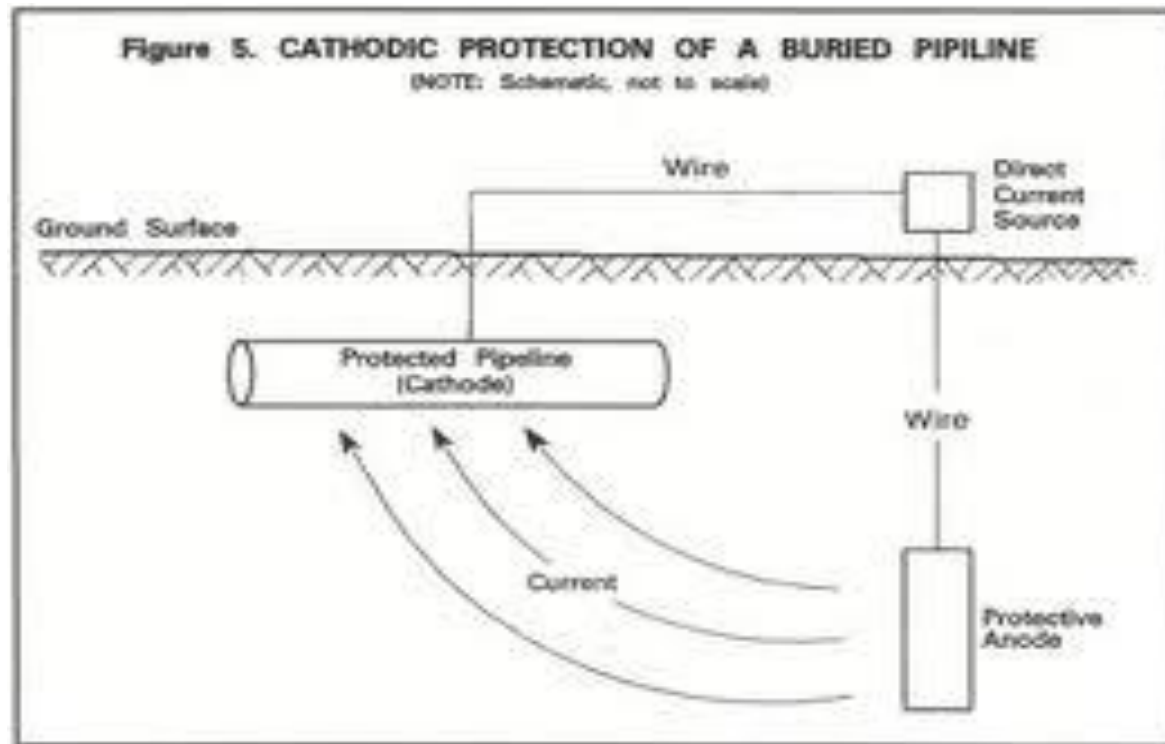
3. Cathodic Protection:

The metal to be protected is forced to behave like cathode.

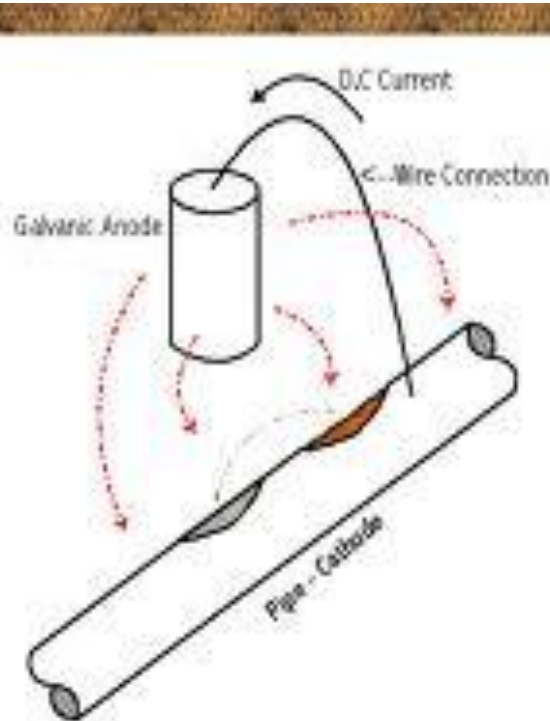
(i) Sacrificial anodic protection:

- Metal to be protected from corrosion connected to more anodic metal

(i) Commonly used metals Mg, Zn, Al and their alloys



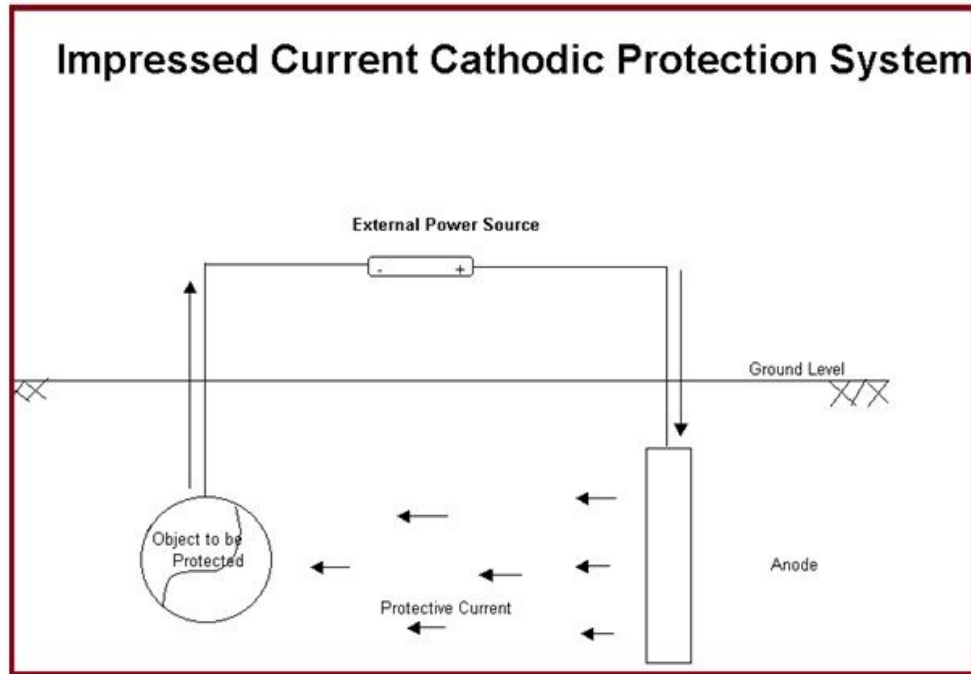
In this method the metal to be protected is connected by a wire to a more anodic metal. The more active metal losses electrons and gets corroded slowly thereby protecting the parent cathodic metal. e.g., Galvanisation process where iron is protected by covering with zinc. Some sacrificial anodes commonly employed are Mg, Zn, Al etc. Applications of this method include underground cables, water tanks etc.



- No external power supply is required.
- Installation is easy
- Low maintenance cost
- **Applications:-**
 - Buried pipelines
 - Underground cables
 - Water tanks

Impressed current method:

- Direct current is applied in opposite direction to nullify the corrosion current.
- Converts the corroding metal from anode to cathode.



Advantages :-

- Large structures can be easily protected.
- It can be useful for wide range of voltage & current.
- Effective coating is obtained.

Disadvantages :-

- Requires periodic maintainance
- Requires external power
- Problem in case of power failure

Applications:- Box cooler, water tanks, buried oil pipes, condensers.

Corrosion

- (b) Electrical 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. The current is derived from direct sources like battery or rectifier on A.C. line with an insoluble anode (graphite, platinum).
This technique is used for long term operations.

4. Modifying Environment

(i) Eliminating dissolved oxygen:

- De-aeration
- By using chemical substances like sodium sulphite and hydrazine. Also called **Deactivation**.

(i) Reducing Moisture:

- Dehumidification by using silica gels

(i) Reducing Acidity:

- Neutralizing the acidic environment by adding lime, NaOH, Ammonia
- Commonly used in refineries

5. Protective coating:

- Application of coating
- Coating material should be chemically inert under particular temp and pressure.

Anodic Protection

- The metal which get easily passivated are protected by forming metal oxide film by application of anodic current.
- Passivity is the phenomenon where metal exhibits higher corrosion resistance than expected from its position in ECS.
- Passivity is common in metals like Al,Cr,Ni,Ti etc
- Metallic tank which is to be protected is connected to potentiostat which maintain constant potential & has reference electrode attached to it.
- Useful for coating chemical reactors, tanks, Pipes carrying corrosive liquids.

Comparison

S. N.	Cathodic protection	Anodic Protection
1	Applicable to all metals	Applicable to metals which shows active passive behaviour
2	The metal to be protected is forced to behave as cathode	The metal to be protected is made more anodic
3	No power source is required	Power source is required
4	Low installation cost	Installation cost is high
5	Standard shape structures are protected	Complex structures can be protected

Protective Coating

Surface preparation for Coating:

1. Cleaning:

- To prepare for suitable condition
- Removing contaminants to prevent detrimental reaction product
- E.g. de-greasing, sand blasting, vapour degreasing, pickling and alkaline cleaning.

1. Solvent Cleaning:

- Must be non-inflammable and nontoxic
- Trichloro trifluoroethane which has low toxicity are costlier
- Vapour de-greasing is economical and advantageous because of continuous cleaning with small quantities of solvent.

1. Electrolyte Pickling:

- Provides better and rapid cleaning by increasing hydrogen evolution resulting in agitation and blasting action
- Sand blasting is mechanical cleaning.

4. **Alkaline Cleaning:**

- Cheaper and less hazardous
- Used in conjunction with surface active (wetting) agent
- Ability depends on pH, rapidly decreases below 8.5
- Other abilities are rinsability, detergent properties, sequestering, wetting etc.

1. **Acid Cleaning**

- Acid such as HCl , H_2SO_4 , H_3PO_4 is very effective.
- 5-10% H_2SO_4 and HCl used to remove inorganic contaminants.
- Pickling are performed at high temp. (60 °C)
- Is effective for removal of grease, oil , dirt and rust.

Metallic Coatings

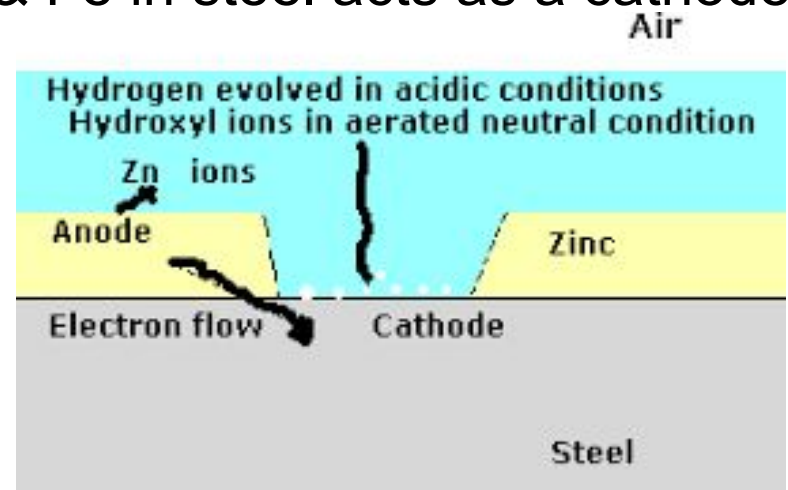
Two types

- a) Anodic coating / Sacrificial coating
- b) Cathodic coating / noble coating

- **Anodic coating:-** Coating metal is having higher position in ECS which acts as a anode with respect to base metal.
- Coating of Zn, Al, Cd on steel
- Steel coated with Zn when having any breaks, crevices or discontinuities then galvanic cell formation takes place
- Zn acts as anode & get corroded & Fe in steel acts as a cathode & prevented from corrosion.

Coating metal:- anode

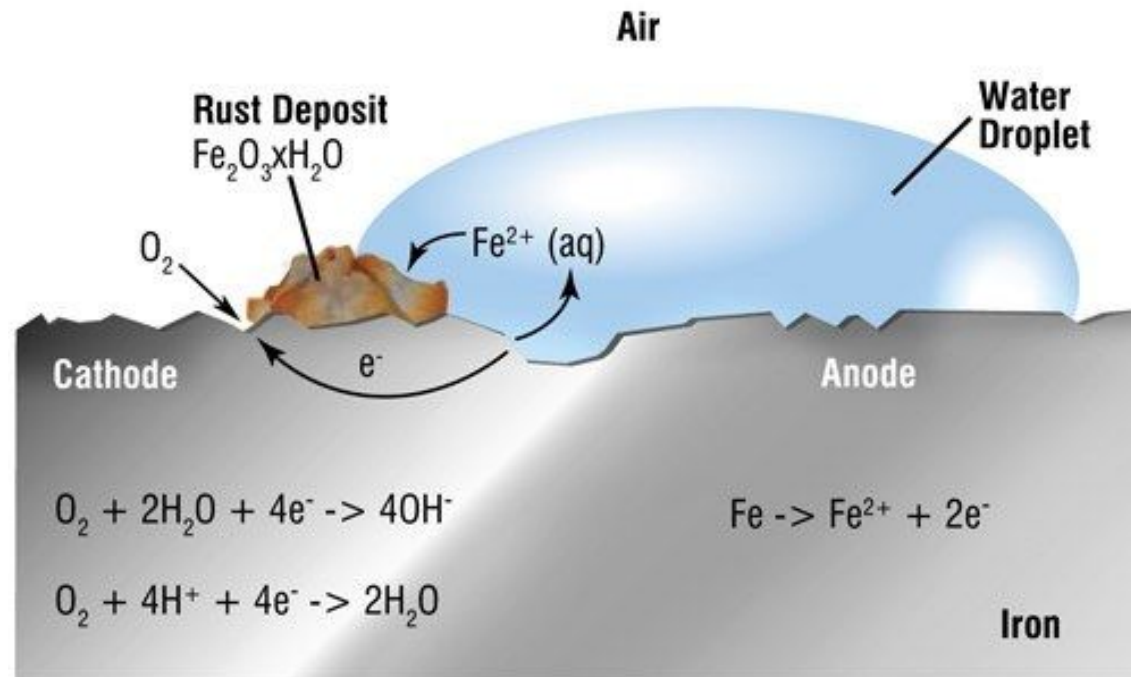
Base metal:- cathode



Cathodic coating/ Noble coating

- Example: Coating of tin (Sn) on iron (Fe)
- Coating metal acts as a cathode & base metal acts as a anode.
- Cathodic coating provides effective protection to the base metal only if the base metal surface is free from pores, breaks.
- If coating is broken galvanic cell formation takes place which leads to pitting corrosion of iron.

Coating metal:- cathode
Base metal:- Anode





Methods of Application of Metallic Coating

1. Hot Dipping:

- Metal is kept in molten state and base metal is dipped into it.
- Used for producing a coating of low M.P
- E.G. Tinning (Tin coating on Iron)
- Process is followed by cooling the coating through a palm oil to prevent oxidation of tin plate to its oxide.
- Palm oil layer is removed by alkaline cleansing agent.



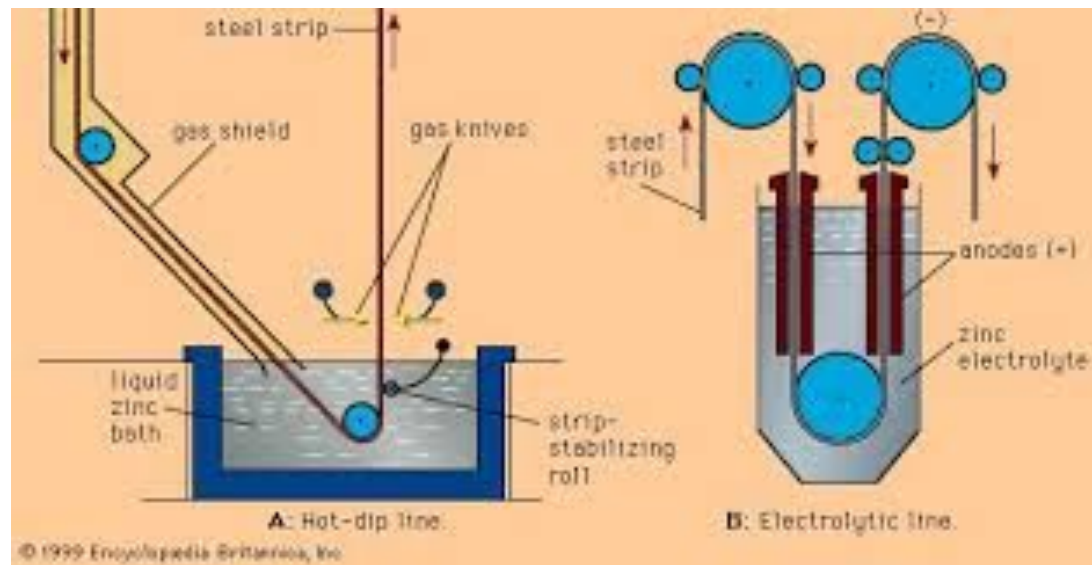
1. Metal Cladding:

- The surface to be protected is sandwiched between two layers of the coating metals and pressed between rollers.
- E.g. Alclad Sheet— Plate of duralumin is sandwiched between 99.5% pure aluminum



Hot dipping

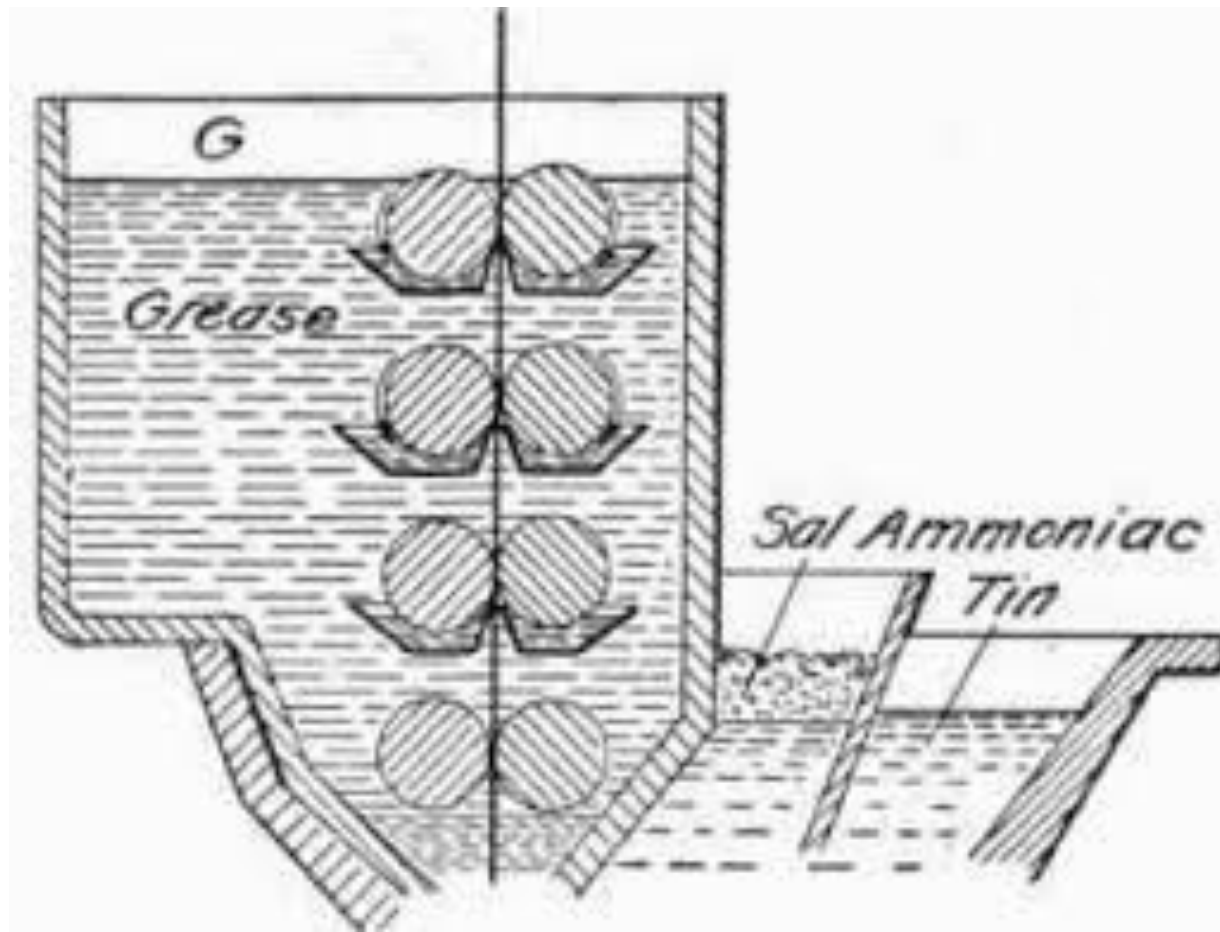
- **Galvanizing:-** The process of coating steel with thin coat of Zn by hot dipping to prevent base metal corrosion is called galvanizing.
- Zn is anodic with respect to base metal.
- Metal surface is cleaned & degreased
- It is treated with H_2SO_4 for 15-20 min at 70-90 C to remove rust & scale
- Then washed with water.
- The metal article is dipped in bath of molten Zn maintained at 425-430 C
- Surface is covered with flux NH_4Cl . It cleans the metal surface before coating for better adhesion & prevents oxidation of molten coating metal.
- It is then passed thr pair of rollers to remove excess of Zn & to produce uniform coating.
- It is annealed at 650 C & cooled to room temp.



- **Applications:-** Used for roofing sheets, wires, pipes, bolts, screws, buckets etc

Tinning

- The process of coating iron or steel with a thin coat of tin by hot dipping to prevent base metal corrosion is called tinning.
- The clean surface of metal is treated with dil. H_2SO_4 to remove oxide film.
- It is then immersed in a flux which will facilitate better adhesion after coating.
- The metal article is then passed through a tank containing molten tin maintained at 240°C
- Finally passed through rollers to remove excess of tin kept submerged in palm oil.
- Palm oil protects the hot tin coated surface against oxidation.



- Applications:-** Tin is non toxic so can be useful for coating iron & steel.
- It is useful for making containers to store food stuffs, oils, ghees etc.
 - Used for making cooking utensils & refrigeration equipment.

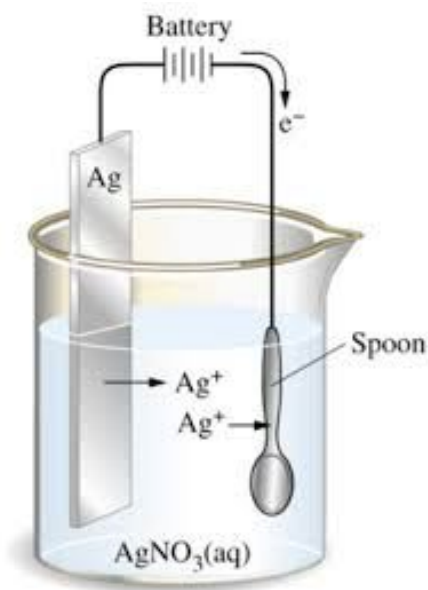
3. Electro Plating:

- Pure metal is made as cathode and base metal as anode.
- Electrochemically coat metal is deposited on base metal.
- This metal gives smooth, fine and uniform coating
- It depends on

(i) Temperature (ii) Current density

(iii) Electrolyte Concentration

(i) Nature of base metal (v) Time



Def:-It is the process by which the coating metal is

deposited on the base metal by passing a direct current thr the solution of an electrolyte, containing the soluble salt of coating metal.

- **Base metal :- Cathode**
- **Coating metal:- anode**

Objectives:

- Increases resistance to corrosion
- Improves physical appearance
- Improves decorative values of metal
- Increases resistant to chemical attack

• Process:-

- **Solvent cleaning:-** Used to remove oils,grease,fatty substances. Organic solvents naphtha, CCl_4 , toluene, actone can be used for cleaning.
- **Alkali solvents:-** Used for removing old paints from metal surface. Trisodium phosphate with soaps & caustic soda are used for this purpose. This treatment followed by washing with mild water & further treatment with acid to neutralize the traces of alkali left.
- **Mechanical cleaning:-**It removes rust. It is done by chisels, scrapers, wire brushes etc.
- **Flame cleaning:-**Metal surface is heated with hot flame to remove moisture & loosely adhering sclaes

- **Sand blasting:-** It is used for removal of oxide film & for getting rough surface Useful for large steel surfaces.
The process includes introducing sand into an air stream under a pressure of 25 to 100 atm. The sand is blasted with high impact on the metal surface. This impact removes scales on metal surface.
- **Pickling:-** It is the process of immersing the metal in acidic or alkaline solution to provide clean, smooth surface.
- **Advantages:-**
 - Coating thickness can be controlled easily.
 - Process is not expensive
 - Fine coatings can be obtained with improved hardness.

Electroless Plating:

Nobel metal is deposited catalytically on less noble metal by using reducing agent without using electrical energy.

Advantage over Electro plating

More economical since no electricity required

Irregular shape can be plated uniformly

Plating on plastics can also be done



5. Metal Spraying:

- Coating is applied by means of spraying device
- E.g. Aluminum is plated in this way on Aircrafts.

Chemical Conversion Coating

- These are formed on metal surface by chemical reaction b/w metal surface and inorganic salt solution
 - Coating base metal is converted into one of the resultant protective film.
 - These films are insoluble, adherent, crystalline or amorphous in nature.
 - Can be done in 3 ways
1. Phosphate coating
 2. Chromate coating
 3. Anodized coating

1. Phosphate Coating

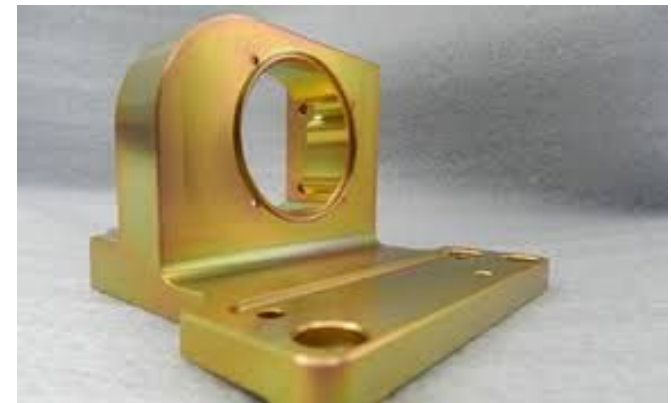
- Produced by chemical reaction b/w base metal and aq. H_3PO_4 , Zn or Fe or Mn Phosphate
- Phosphate coating are applied on Iron, Steel, and Zinc
- Film formed on base metal after coating consist of Zn-Fe, Mn-Fe Phosphates.



1. Chromate Coating

Produced by dipping the base metal in Potassium chromate (acidic) followed by immersion in neutral chromate bath.

- Resulting film consist of trivalent and hexavalent chromium.
- Used as base for paints, lacquers and enamels.



3. Anodized Coating

- Formed by anodic oxidation process
- This is produced on non-ferrous metals like Al, Zn, Mg
- In this method base metal is made as anode
- Process is carried out by passing moderate direct current through a bath in which the metal is suspended as anode.
- Coating are formed as a result of Progressive oxidation starting at surface of base metal.

