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Unit 5: Corrosion and its Prevention

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* Introduction:

Metals with the exception of the noble metals Ag, Au, Pt etc. are usually found in nature in their combined form such as oxides, sulphides, sulphates, carbonates, silicates, etc. are known as Minerals. The naturally combined form of the metal is more stable than the other metal. Hence the metal after extraction from the mineral tends to revert back to the stable natural combined form when it comes in contact with the other elements in the environment. The surfaces of almost all metals begin to decay more or less rapidly when exposed to gaseous atmosphere, water or any other reactive liquid medium. If the process is allowed to continue to completion, the metals are chemically converted to the new products which are usually in the form of oxides, hydrated oxides, carbonates, sulphides, sulphates, etc. Such a process of chemical decay of metals due to the action of the surrounding medium is called corrosion. In other words, corrosion is unwanted reaction or deterioration of a metal component by the direct chemical attack of environment or electrochemical attack.

• Definition:

Any process of an unwanted deterioration of metal by chemical or electrochemical reaction by the environment, starting at the surface and resulting in loss of solid metallic component due to formation of other metallic compounds, is called corrosion.

• Examples:

i) The most familiar example of corrosion is rusting of iron.

When iron is exposed to an aqueous environment containing dissolved oxygen it tends to revert back to its oxide.

$\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ which corresponds in composition to the naturally occurring mineral haematite.

ii) Green coating of basic carbonate containing $\text{CuCO}_3 + \text{Cu}(\text{OH})_2$ on the surface of copper.

iii) Tarnishing of silver due to black coating of silver sulphide.

* Consequences of corrosion:

- Due to corrosion the strength of material gets reduced, the properties of metals like malleability, ductility gets loosed slowly and if the unwanted process is not stopped then metal gets corroded completely.
- The process of corrosion is very harmful and is responsible for the enormous waste of machineries and different type of metallic materials. The corrosion can lead to unpredictable machinery failure even explosion and thus loss of life.
- Food packed in metal containers may be spoiled and contamination of potable water in sanitary lines may be takes place on account of corrosion process.
- It has been calculated, for instance, that the amount of iron wasted each year by corrosion is about $\frac{1}{4}$ th of its annual world production. The expenses for the protection of metals against the corrosion are also enormous. Metallic corrosion cost the world's several billion dollars annually.
- For the above reasons the study of corrosion and its prevention is of vital importance to the engineer.

* Theories of Corrosion:

- 1) Dry or Direct chemical corrosion.
- 2) Wet or Electrochemical corrosion.

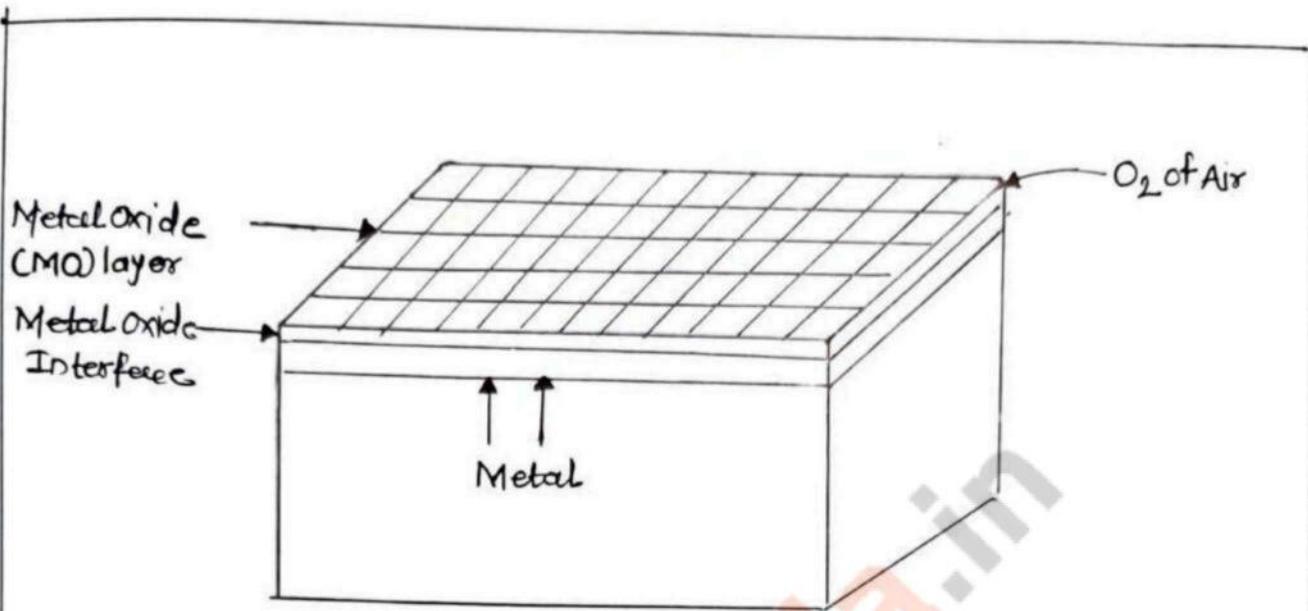
i) Dry or Direct chemical corrosion:

This type of corrosion occurs due to direct attack of atmospheric gases like oxygen, carbon dioxide, sulphur dioxide, hydrogen sulphide, chlorine, nitrogen oxides etc., moisture and by hot flowing liquids. The surface of metals, thus directly attacked by these gases present in the surrounding medium, become coated with the corresponding compounds, namely oxides, sulphides, basic carbonates etc. The corrosion product may be solid or liquid. The solid product may be soluble or insoluble. The insoluble product generally form a compact layer protecting the metal from further attack as these products are generally inert to atmosphere and do not allow air, moisture, chemicals to penetrate and attack on underlying fresh metal. The soluble or liquid products are easily removed from the surface as soon as they are formed, so the process of corrosion continues.

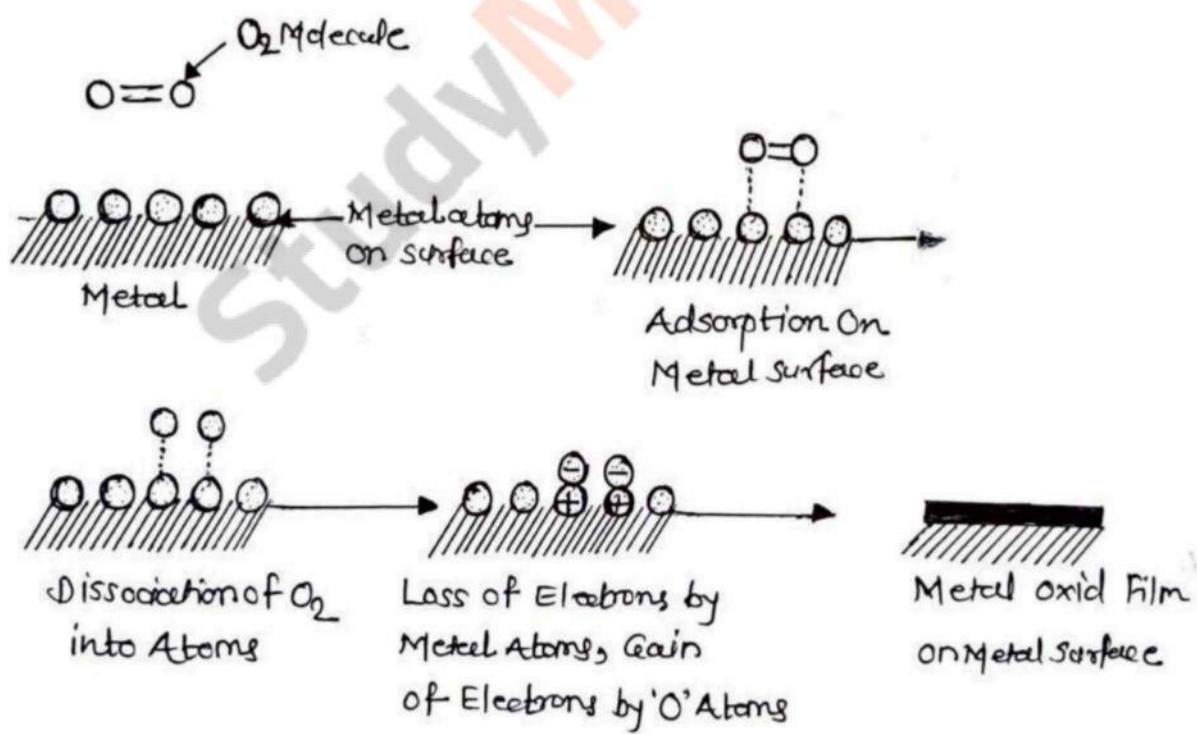
Dry or direct chemical corrosion are generally of three types:-

A] Oxidation Corrosion:-

- It has been found that oxygen present in the medium is responsible for the corrosion of metals to a greater extent.
- oxygen under ordinary conditions directly attacks the metals and forms thin film of oxides on their surfaces.



* Mechanism of Oxidation corrosion *



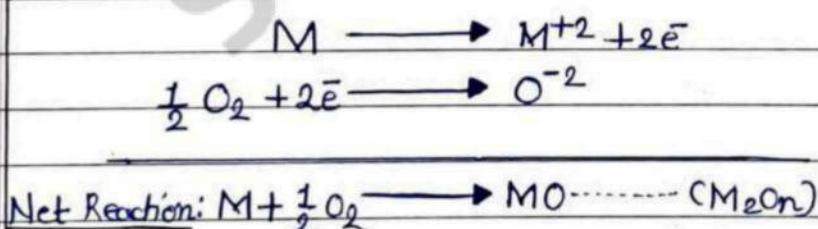
* Mechanism of O₂ attack *

- At higher temperatures practically all metals except noble metals (i.e. Ag, Au, Pt etc.) are attacked by the oxygen to some extent and their surfaces get converted to their respective oxides. If surface of metal is attacked by oxygen then further corrosion of the underlying metal depends upon the nature of oxide film formed on the surface of metal.

* Mechanism of oxidation corrosion:

The formation of oxide layer on the metal surface proceeds as follows:

- Adsorption of O_2 molecules on metal surface.
- Dissociation of O_2 molecules into atoms
- Loss of electrons by metal atom (being electro-positive), resulting in the formation of metal ion by oxidation
- Oxygen is converted to oxide ion due to the transfer of electrons from metal atom.
- Formation of metal oxide by union of the ions and leading finally to form thin layer or film of Metal oxide on the surface of metal.



- Iron forms Fe_2O_3 , chromium forms Cr_2O_3 , zinc forms ZnO , aluminium forms Al_2O_3 , copper forms CuO , on corrosion by oxygen. [Thickness of film is less than 300 \AA (i.e. 300 nm), generally, if thickness is more than 300 \AA then it is called scale.]

* Nature of Oxide Film:

The nature of oxide film plays an important part in the further corrosion to continue or not. Oxide films occur in following forms:

- i) Stable oxide film.
- ii) Unstable oxide film.
- iii) Volatile oxide film.
- iv) Porous oxide film.

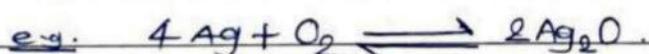
i) Stable oxide film:-

If the oxide film is stable, non-porous, well adhered to the metal surface, then further corrosion stops, as the oxide film formed after some initial corrosion of surface, acts as a barrier and detaches the underlying metal from the corroding oxygen or other gases.

Such a stable layer is formed on the surfaces of metals like Aluminium, Copper, Nickel, Tin, Chromium, zinc, Lead etc. The further deterioration of such metals is stopped. The main consequence of oxidative corrosion is the loss of shiny appearance of metal, i.e. metals get tarnished.

ii) Unstable oxide film:-

If the metal oxide film formed is unstable, i.e., the reaction is reversible, there is no noticeable oxidation corrosion.



Noble metals like gold (Au), silver (Ag) and platinum (Pt) undergoes reversible reaction with atmospheric oxygen, hence do not corrode.

iii) Volatile oxide film:-

In such case, corrosion is rapid and product leaves the surface as soon as it is formed so new metal atoms are easily attacked by oxygen.

e.g. Molybdenum Oxide (Mo_2O_5) film is volatile.



iv) Porous oxide film:-

If the oxide film is porous, then through the pores, oxygen gas molecules penetrate and continues the corrosion of the underlying metal until whole metal gets destroyed.

e.g. Oxide films of Iron (Steel), magnesium, sodium, potassium, calcium metals are porous.

* Pilling-Red Worth rule:

The oxide layer may be protective (stops further corrosion) or non-protective (corrosion continues) depending on pilling-red worth ratio which is given by -

Pilling-Red worth ratio =
$$\frac{\text{Volume of metal oxide formed on the surface}}{\text{Volume of metal consumed}}$$

According to it "an oxide is protective or non-porous, if the volume of the oxide is atleast as great as the volume of the metal from which it is formed." On the other hand, "if the volume of the oxide is less than the volume of metal, the oxide layer is non-protective or porous, because it cannot prevent the access of oxygen to the fresh metal surface below." Thus alkali and alkaline-earth metals like Li, K, Na, Mg form oxides of volume less than the

volume of metals. Consequently, the oxide layer faces stress and strains, thereby developing cracks and pores in its structure and through the pores, oxygen gas molecules penetrate and continues the corrosion of underlying metal until whole metal gets destroyed.

On the other hand, metals like Al forms oxide, whose volume is greater than the volume of metal, consequently, an extremely strong-adhering, non-porous, stable layer is formed. Due to the absence of any pores or cracks in the oxide film, the rate of oxidation rapidly decreases to zero.

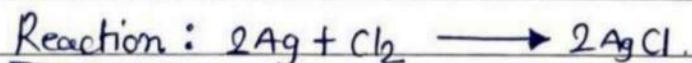
B) Corrosion by other Gases :-

The gases like SO_2 , CO_2 , H_2S , Cl_2 , F_2 also corrode the metal. The extent of corrosion depends upon the affinity of metal with these gases. The layer of corrosion product may be protective or non-protective depending on whether it is non-porous or porous.

e.g. The corrosion process of tin (Sn) by chlorine is unidirectional as the corrosion product SnCl_4 is volatile. Reaction: $\text{Sn} + 2\text{Cl}_2 \rightarrow \text{SnCl}_4 \uparrow$

Similarly formation of Iron Sulphide (FeS) scale on iron in petroleum industry is non-protective as FeS forms porous layer. Reaction: $\text{Fe} + \text{H}_2\text{S} \rightarrow \text{FeS} + \text{H}_2 \uparrow$

The coating of silver chloride or silver sulphide on the surface of silver is non-porous and protective.



C] Liquid-metal corrosion / corrosion by Liquid metals :-

Such types of dry corrosion generally occurs in devices used at higher temperature. The metals like sodium having low melting point flows on the other metals & alloys and cause corrosion either by dissolving solid metal in it or penetrating into solid metal, or alloys. Such corrosion reduces the strength of solid metal components.

The metals like Li, Hg, Na, K, Mg, Sn, Pb, etc. and fused salts have low melting points, have the corrosion action on metals.

2) Wet or Electrochemical Corrosion:

Definition:

Corrosion of a metal by aqueous conducting medium, with the formation of anodic and cathodic areas, is known as wet or electrochemical or immersed corrosion.

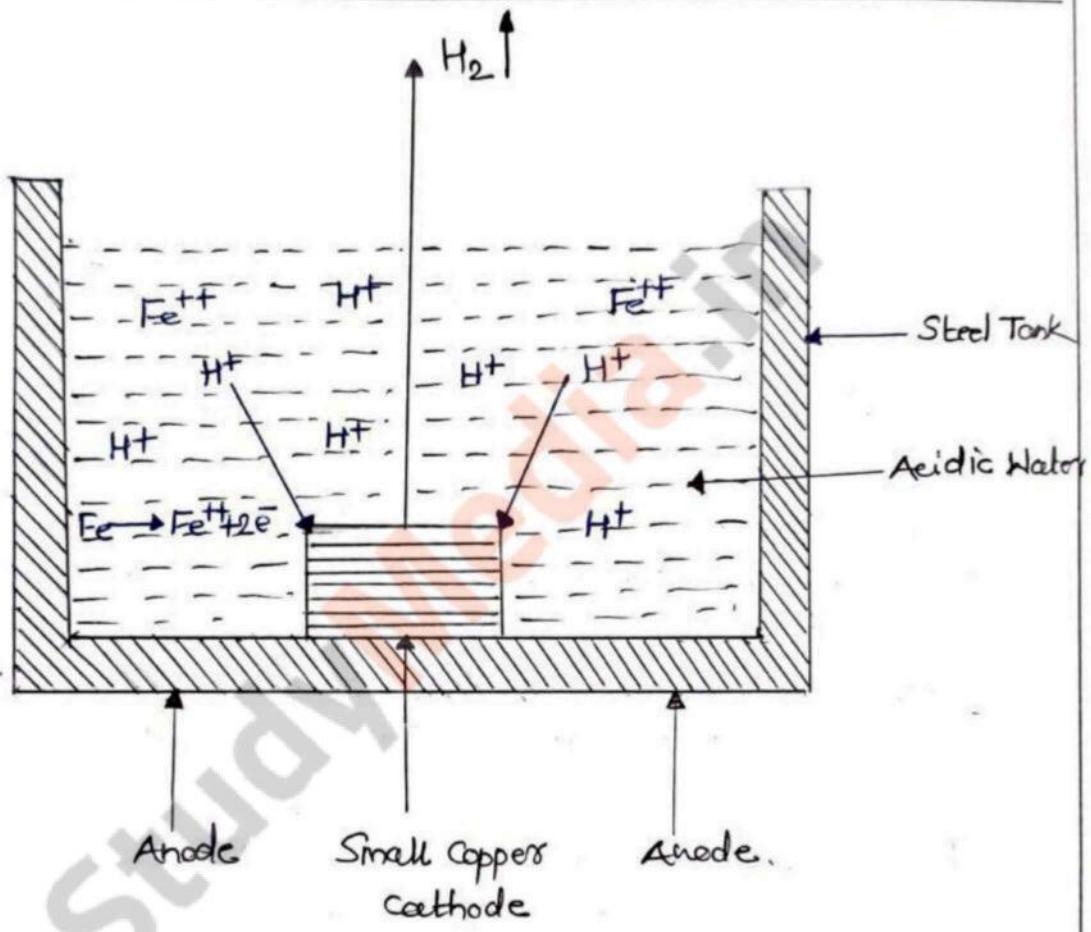
Theory:

- This type of corrosion occurs at a solid-liquid interface when the metals are in contact with the moist air or any liquid medium.
- The corrosion involves anodic and cathodic area formation and corrosion occurs on anodic area only, while corrosion product either remains dissolved in medium or deposits on cathode.
- The wet corrosion takes place by the formation of several types of electrolytic cells, mainly galvanic or concentration cells of different magnitude depending upon the nature of the metal and the surrounding medium, which ultimately promote the corrosion of the metal.

- Galvanic cells are set up when two dissimilar metals come in contact with each other and are surrounded by moist air or liquid medium. Whereas the concentration cells are set up when a metal is surrounded by aqueous medium with difference of ion concentration in solution.
- The most familiar examples of electrochemical corrosion are - i) Rusting of fencing wire underpint, ii) corrosion at riveted joints, iii) Cu-sheets joined by iron nails etc.
- Wet corrosion or electrochemical corrosion involves flow of electron current between anodic and cathodic areas. The reaction at anode is dissolution of metal as its metallic ion with the liberation of free electrons. The reaction at cathode is consumption of electrons with - a) Evolution of hydrogen gas or
b) Absorption of O₂, depending upon the nature of environment.

② Hydrogen Evolution Mechanism:

- This mechanism occurs when corrosive medium (electrolyte) is acid solution and amount of dissolved oxygen is low. The reaction at anode, is the formation of metal ions which pass into the solution. The reaction at cathode consists of, formation of hydrogen gas.
- In such mechanism, metal ions dissolve in solution, hydrogen ions comes out of solution in the form of gas. Thus all metals having positive values of electrode potential dissolve in acid solution.

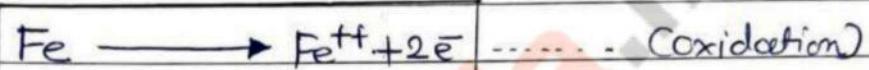


* Hydrogen Evolution Mechanism *

In such type of mechanisms, the anodes are generally of large areas and cathode of small areas.

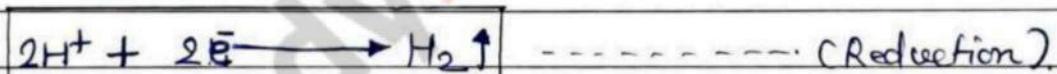
- For example, consider a steel tank, containing acidic solution and a small piece of copper scrap is in contact with the steel tank. In this case, the portion of the steel tank, in contact with copper gets corroded most with the evolution of hydrogen gas.

The chemical reactions are -

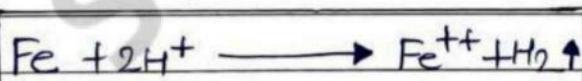


- These free electrons concentrate on cathode (copper) by flowing through the metal.

The hydrogen ions, which are present in the acid, get concentrated on cathode and take up the electrons and evolve as gas.

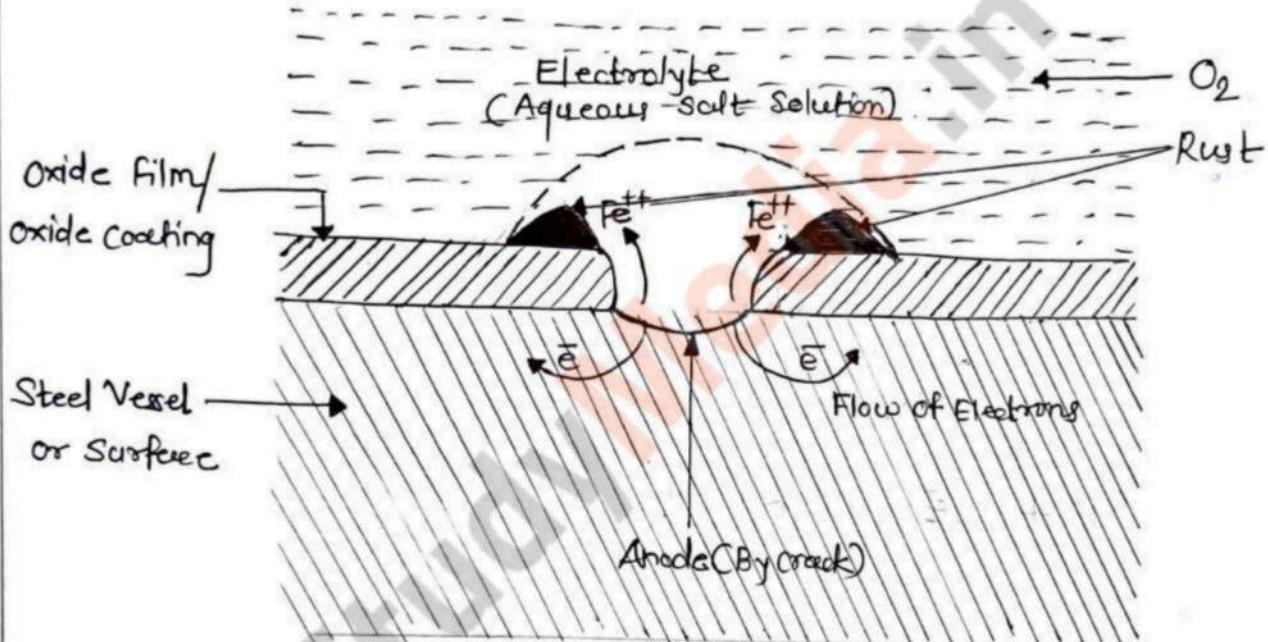


Thus, overall reaction is :



- The hydrogen gas so evolved tends to concentrate on the surface and thus forms an insulating layer and slows down or stops the electrochemical action. This is known as Cathodic polarization.

If the hydrogen layer get broken down at the surface or swept away by some other reaction, the initial conditions are restored, current will begin to flow and corrosion will start once again.

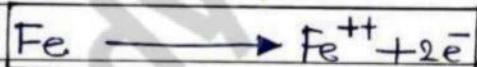


* Oxygen Absorption Mechanism *

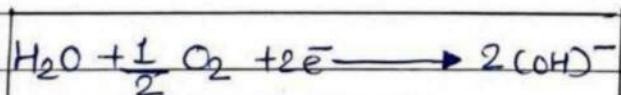
b) Oxygen Absorption Mechanism:

- This mechanism of corrosion occurs when dissolved oxygen is present in the electrolyte. Consider a situation that an iron vessel contains salt solution containing dissolved gases. The surface of vessel contains an oxide film coating of metal. However, if this oxide film develops some cracks, due to presence of crack, the iron surface will directly come into contact with the electrolyte.
- This surface of crack, will act as anode and the surface of oxide coating will act as cathode.
- Corrosion occurs in the following way:

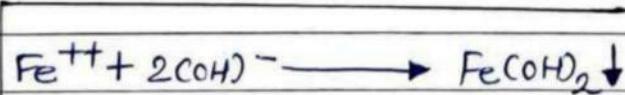
At anode area (metal under the crack) of iron surface, iron goes into solution as ions with the liberation of electrons.



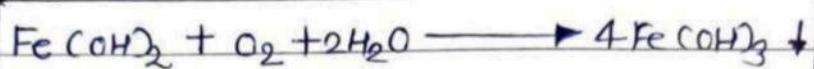
- On the large cathodic area, electrons flow through the iron metal from anode area to cathode area. As oxygen is also present in the solution, the following reaction occurs at cathode.



- The Fe^{++} ions formed, travel rapidly towards cathode and combine with $(\text{OH})^-$ ions, and forms ferrous hydroxide, which is soft brown rust.



- If enough oxygen is present in medium, ferrous hydroxide is easily oxidised to ferric hydroxide which is hard rust.



This hard rust is less soluble and is precipitated very near to anode area and forms a protective layer. This layer, decreases corrosion rate.

- The rusting of iron is a slow process because the rust is heavier than pure atom of Fe. The rate of corrosion can be measured by putting a reweighted sample of iron in corrosive environment and measuring the amount of rust formed at different intervals of time.

* Factors Affecting The Rate of Corrosion:

The various factors affecting corrosion can be divided into two categories:

- i. Nature of the metal, and
- ii. Nature of the environment.

i] Nature of the metal:-

So many characteristic properties of metal are responsible for corrosion. These are as follows;

i) position of metal in galvanic series:-

- A metal having higher position in galvanic series, has more chemical reactivity and therefore, it gets attacked by gaseous corroding medium faster. However, if the film of the corrosion product is non-porous, then corrosion stops naturally.
- When two dissimilar metals are in contact in an aqueous medium, then the metal having higher position in galvanic series, gets corroded.
- Greater the difference in their positions, faster is the rate of corrosion by the electrochemical mechanism.

ii) Purity of the metal:-

- Impurities present in the metal cause non-homogeneous metal surface and forms large number of tiny galvanic cells when an aqueous medium comes in contact with such a metal.
- If the impurity metal is highly placed in galvanic series then it acts as a anode and gets corroded to produce

small depressions on the surface of the base metal.

- Thus, corrosion resistance of a metal can be improved by increasing its purity.

iii) Relative areas of anode and cathode :-

- Small anodic and large cathodic areas causes high corrosion.
- The reason behind this is that the current density at small anodic area is high and demand of these electrons by large cathode is only fulfilled by high corrosion rate at small anode.

e.g. Small steel pipe filled in a large copper tank

iv) Solubility of corrosion product :-

- If corrosion product is soluble in corroding medium, the corrosion of the metal proceeds faster.
 - Insoluble corrosion product functions as a physical barrier, thereby, suppresses further corrosion.
- e.g. Pb in H_2SO_4 medium forms $PbSO_4$, which is insoluble in the corroding medium (H_2SO_4), hence corrosion proceeds at a smaller rate.

v) Nature of the oxide film :-

- Every metal (except noble metals) gets covered by a thin oxide film in corroding environment.
- If the film is non-porous then the metal safeguards itself from further corrosion. But if the film is porous then the corrosion by the gas continues until total destruction of the metal.

2] Nature of Environment:

The environment in which metal is working is also responsible for corrosion. Different environmental factors which affects the rate of corrosion are as follows;

i) Temperature:-

- i) • Corrosion is enhanced at high temperature due to increased rate in diffusion.
- The rate of atmospheric and electrochemical corrosion become faster at higher temperature. Gas molecules and metal atoms, both become more active in dry corrosion at high temperature also the cell reactions become faster during wet corrosion, at higher temperature.

ii) Humidity:-

- The greater the humidity, the greater is the rate and extent of corrosion.
- If the moisture percentage is high, then it can act as aqueous conducting medium and causes setting up of cells. Thus high humidity brings about electrochemical corrosion.
- We know that generally the rate of electrochemical corrosion is faster than the rate of atmospheric corrosion.
e.g. Atmospheric corrosion of Fe is slow in dry air as compared to moist air.

iii) Effect of pH:-

- Corrosion of those metals which are readily attacked by acids can be reduced by increasing the pH of the attacking environment.
- In general, acidic media are more corrosive than alkaline and neutral media.

iv) Presence of impurities in atmosphere:-

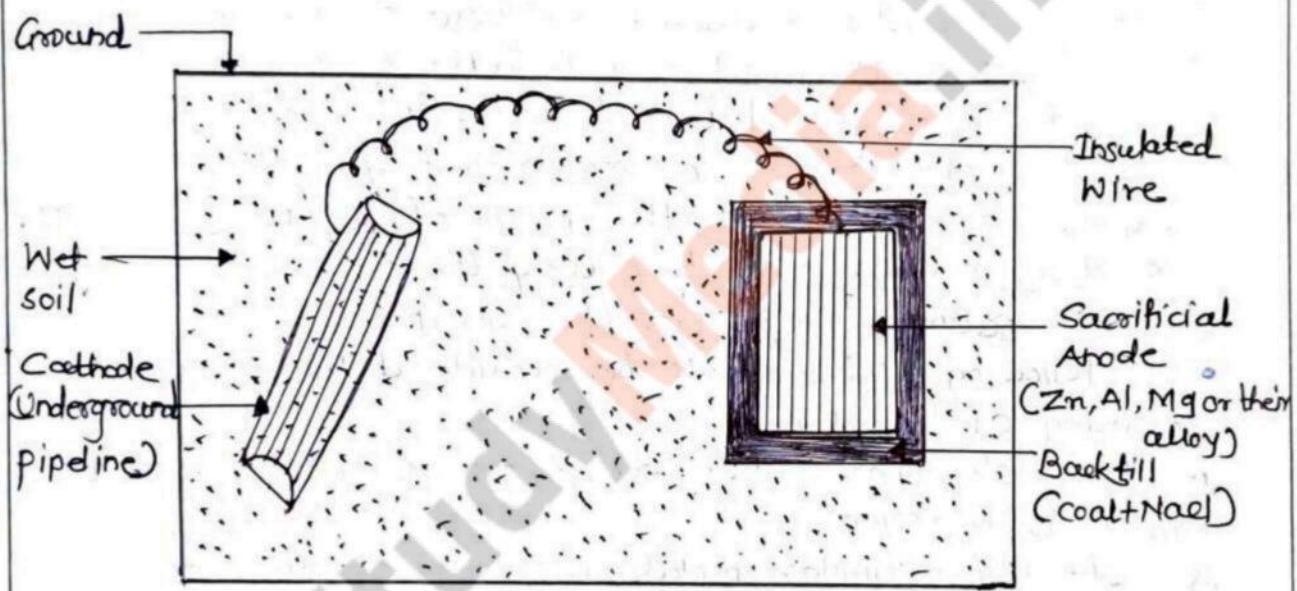
- Presence of corrosive gases like CO_2 , H_2S , SO_2 and fumes of HCl , H_2SO_4 in atmosphere increases high acidity and high electrical conductivity which causes high corrosion.
- Another similarity belongs to marine atmosphere in which presence of Sodium chloride (NaCl) and other salts creates high electrical conductivity and high corrosion.

v) Conductance of the corroding medium:-

- This factor is important in ~~underground~~ corrosion. Corrosion in mineralized soil is high in comparison to sandy soil because conductivity in mineralized soil is higher due to presence of salts.

vi) Nature of ions present:-

Various ions present in environment affect corrosion in different ways e.g. If silicate ions are present, they form insoluble reaction product silica gel which inhibits corrosion. Chloride and Ammonium ions destroy the protective layer and increases the corrosion rate.



* Cathodic protection using Sacrificial anode *

* Cathodic Protection:

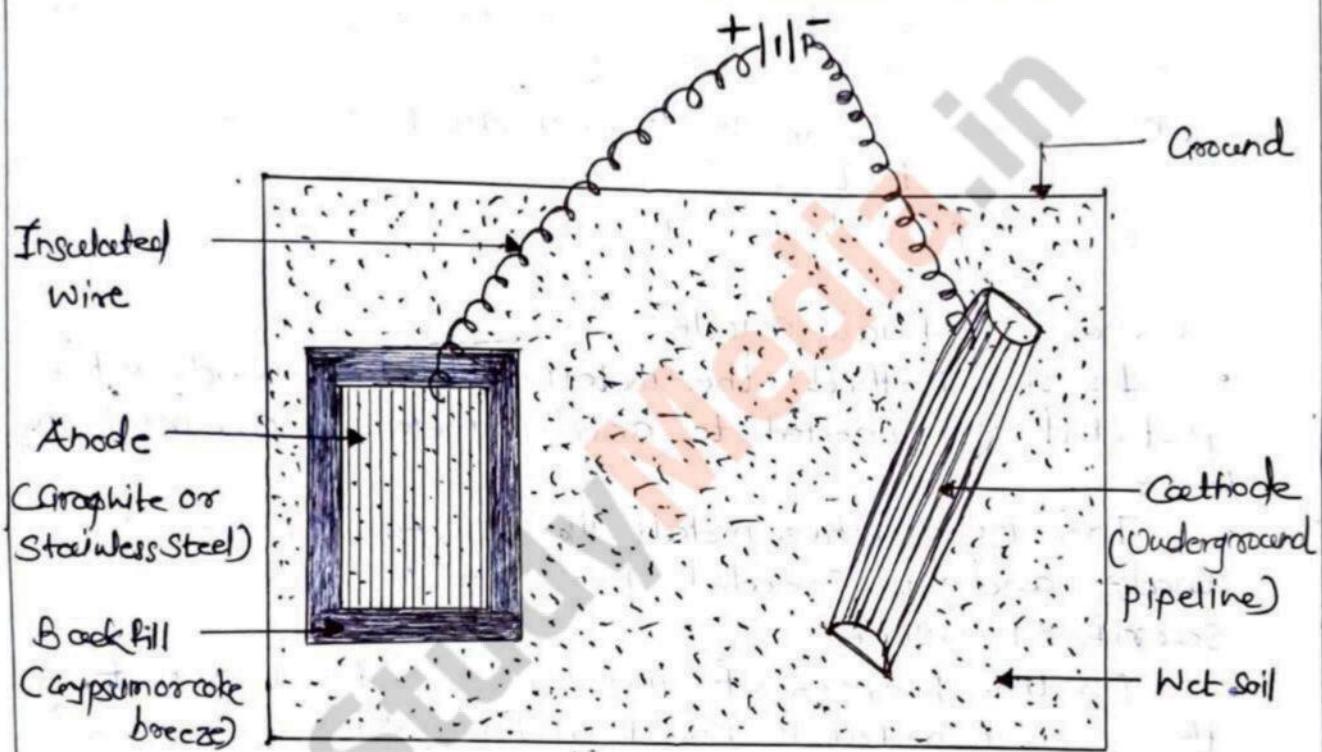
Cathodic protection, is one of the most important method to control corrosion of machine parts immersed in Soil or liquid. The principle of this method is, the metal to be protected is forced to behave as a cathode.

There are two ways to do cathodic protection:

- i) Using sacrificial anode.
- ii) Using impressed current.

i) Using Sacrificial anode:

- In this method, the metallic structure which is to be protected is connected to anodic metal by an insulating wire.
- The more active metals like Zn, Al, Mg, etc. acts as anode and gets corroded, hence it is called as sacrificial anode.
- For the purpose of increasing electrical contact, the active metal is placed in backfill: (Coal + NaCl)
- When the sacrificial metal is consumed completely, it is replaced by fresh piece.
- This method of corrosion control is used in following areas:
 - a) For protecting buried pipe lines of oil & water.
 - b) Protecting marine structure, ship parts, etc.
 - c) Protecting domestic water boilers or tanks.



* Cathodic Protection by Impressed Current *

ii) Using impressed current:

- 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 impressed current is derived from a D.C. source and given to insoluble anode like graphite, stainless steel or scrap iron, buried in soil. The negative terminal of D.C. source is connected to the pipeline to be protected.
- The anode is kept in backfill such as coke breeze or gypsum to increase the electrical contact between itself and the surrounding soil.
- There may be a single anode (as in simple applications) or many anodes (as in pipelines).
- This type of cathodic protection is applicable to: Buried structures such as tanks and pipelines, transmission line towers, marine piers, condensers, etc.
- Impressed current systems are particularly useful when current requirements and electrolyte resistivity are high.
- They, however, require a cheap source of electrical power, but are well-suited for large structures and long-term operation. They can be automatically controlled which reduces maintenance and operating costs.

Metallic coatings:

The surface of the base metal coated with another metal (coating metal) is called metallic coatings. Metallic coatings are broadly classified into anodic and cathodic coatings.

1. Anodic coating:

- The metal used for the surface coating is more anodic than the base metal which is to be protected.
- For example, coating of Al, Cd and Zn on steel surface are anodic because their electrode potentials are lower than that of the base metal iron. Therefore, anodic coatings protect the underlying base metal sacrificially.
- The formation of pores and cracks over the metallic coating exposes the base metal and a galvanic cell is formed between the base metal and coating metal. The coating metal dissolves anodically and the base metal is protected.

1. Cathodic coating:

- Cathodic coatings are obtained by coating a more noble metal (i.e. metals having higher electrode potential like Sn, Au, Ag, Pt etc.) than the base metal. They protect the base metal as they have higher corrosion resistance than the base metal due to cathodic nature.
- Cathodic coating protects the base metal only when the coating is uniform and free from pores.
- The formation of pores over the cathodic coating exposes the base metal (anode) to environment and a galvanic cell is set up. This causes more damage to the base metal.

Methods of application of metallic coatings:

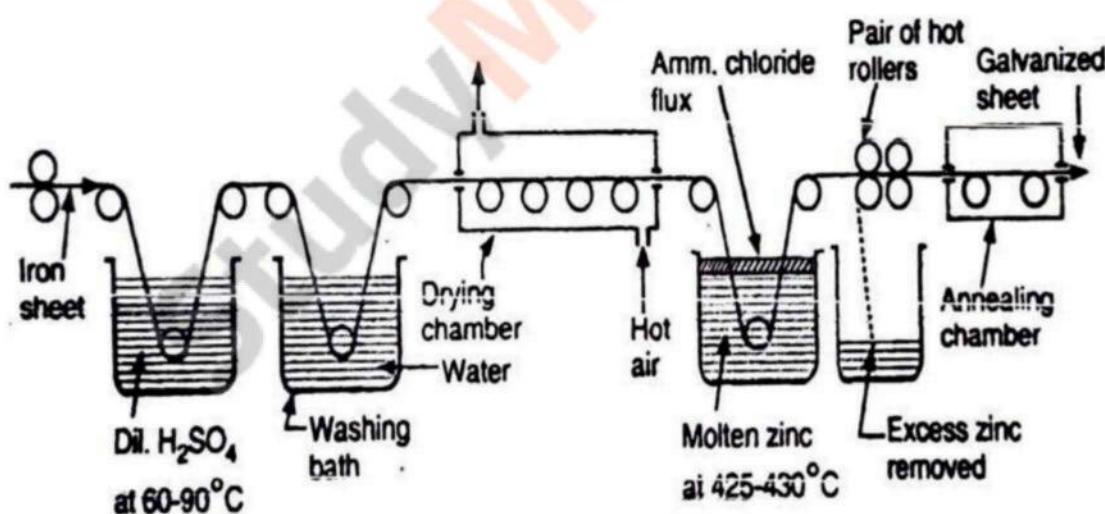
1. Hot dipping:

- Hot dipping process is applicable to the metals having higher melting point than the coating metal.
- It is carried out by immersing a well cleaned base metal in a bath containing molten coating metal and a flux layer.
- The flux cleans the surface of the base metal and prevents the oxidation of the molten coating metal. Eg: Coating of Zn, Pb, Al on iron and steel surfaces.
The most widely used hot dipping processes are
 - (a) Galvanizing
 - (b) Tinning

Galvanizing:

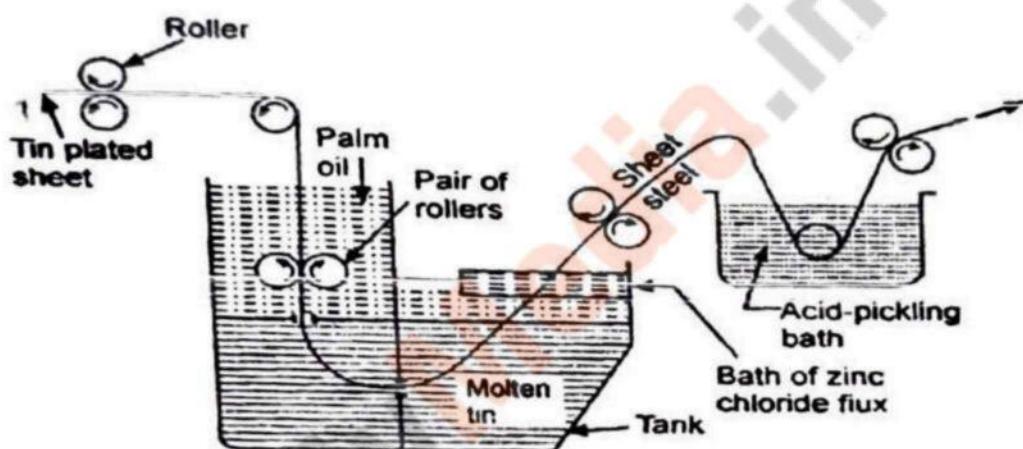
- Galvanizing is a process in which the iron article is protected from corrosion by coating it with a thin layer of zinc.
- It is the anodic protection offered by the zinc.
- In this process, at first iron or steel is cleaned by pickling with dil. H_2SO_4 solution for 15-20 minutes at $60-90^{\circ}C$. In pickling any scale, dirt, oil, grease or rust and any other impurities are removed from the metal surface.
- The article is washed well and then dried.
- It is then dipped in bath of molten zinc maintained at $425-430^{\circ}C$.
- The surface of bath is kept covered with ammonium chloride – flux to prevent oxide formation. The article is covered with a thin layer of zinc when it is taken out of bath.
- It is then passed through a pair of hot rollers, which removes any excess of zinc and produces a thin film of uniform thickness
- Then it is annealed and finally cooled slowly.

Applications: Galvanizing is widely used for protecting iron exposed to the atmosphere (roofs, wire fences, pipes etc.) Galvanized metallic sheets are not used for keeping eatables because of the solubility of zinc.



Tinning

- The process of coating tin over the iron or steel articles to protect them from undergoing corrosion is known as tinning.
- Tin is a noble metal and therefore it possesses more resistance to chemical attack. It is the cathodic protection offered by the tin. In this process, iron sheet is treated in dilute sulphuric acid (pickling) to remove any oxide film, if present.
- A cleaned iron sheet is passed through a bath of $ZnCl_2$ molten flux followed by molten tin and finally through a suitable vegetable oil. The $ZnCl_2$ flux helps the molten metal to adhere to the base metallic surface.
- Palm oil protects the tin coated surface against oxidation.
- Finally, the sheet is passed through rollers to remove excess of tin and produce thin coat of tin of uniform thickness



Applications:

1. Tin metal possess good resistance against atmospheric corrosion. Tin is non-toxic and widely used for coating steel, copper and brass sheets
2. The containers coated with tin are used for storing food stuffs, ghee, oil etc and packing food materials.
3. Tinned copper sheets are used for making cooking utensils and refrigeration equipment.

Corrosion Resistant Paint / Anti Corrosive Paints: -

Introduction:

Corrosion is considered as the silent enemy of many metals as it affects the strength and durability of infrastructures in all countries due to reduction in efficiency, leading to plant shutdowns, waste of valuable resources, loss or contamination of products which results in increase in maintenance cost. In addition, it also risks safety and inhibits technological progress and this involves annual losses of billion dollars worldwide.

So, there has been a need to find suitable prevention methods (Coatings) which are environmentally friendly and effective to inhibit corrosion of metals.

1. Use of metal nanoparticles in paints:

- Nanoparticles of metal like Cu can be used in corrosion resistant paints.

As copper nanoparticles tend to aggregate during synthesis so, surfactants, polymers and ligands need to be used as stabilizers in aqueous media, which prevents agglomeration and yield highly stable, well dispersed metal nanoparticles.

The 0.5 wt% of prepared CuNPs capped by the surfactant shows the maximum corrosion inhibition efficiency for steel anti corrosion coating when compared with 1%, 2%, 4 % and 0% CuNPs in paints.

2. Use of metal oxide nanoparticles in paints

- Use of epoxy resins in paints are safe and reliable, with many advantageous features such as good adhesion, small shrinkage, good acid and alkali resistance, good insulation and easy processing.

The introduction of inorganic nanoparticles of various metal oxides like ZnO, Al₂O₃, Cr₂O₃, SiO₂, TiO₂ etc. into a resin, can result in more homogeneous coatings and offer better barrier properties.

The effect of adding different metal oxides as nanofillers to an epoxy coating found an increase in the corrosion resistance compared to the epoxy - coated steels without the nanoparticles, as nanoparticles occupies the spaces with defects that are formed while the epoxy is curing.

- The performance of the coatings is largely affected by the amount and the particle size of the metal oxide, e.g. among many of the nanoparticles, Nano ZnO are highly active, non-toxic and sacrificial in nature.

Thus, the Zn doped resins effectively fill the microporous surface of the carbon - steel substrate and exhibit improved wetting properties, resulting in the hydrophobicity of the surface and thus add another advantage to coating industry.

3. Use of conducting polymer nanoparticles in paints:

- Conducting Polymer Nano Particles (CPNs) like polyaniline, polypyrrole and polythiophene can also be used in polymeric coatings to protect steel against corrosion.

These coatings are useful due to their low cost, ease of process, high conductivity, environmental stability and redox properties, which can interact with the metal substrate and form a passive layer to inhibit corrosion process.

It has been observed that incorporation of CPNs in the blank paint formulation make the paint films acquire higher resistance against washability, weathering and corrosion than those of paint formulation

based on St/BA emulsion alone. Such a new type of emulsion paint containing CPNs can be used as an architectural paint to reduce the consumption of the petroleum resources in the field of paint industry and provide a path for the development of new coating technologies.

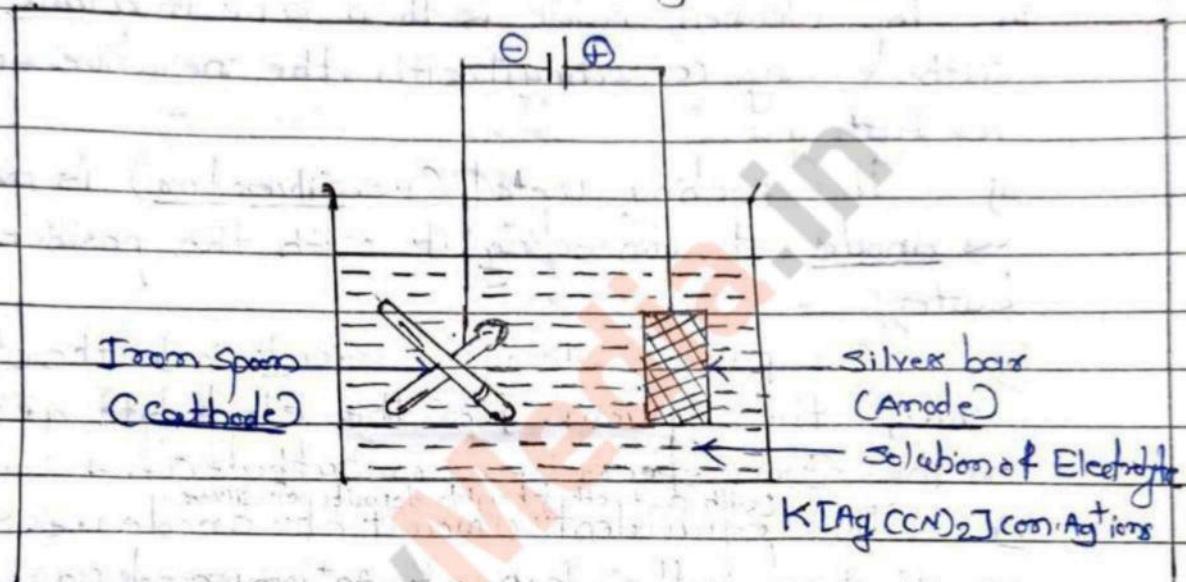
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e) Explain electroplating process with example.

• Definition :-

The process of producing metallic coating of more resistant metals (like Silver, gold, nickel, platinum etc.) on the base metal with the help of electric current.

• Diagram :- e.g. Electroplating of Silver.



• Purpose of Electroplating:-

Electroplating is done to achieve following objectives:

i) Decoration \Rightarrow Electroplating of a superior metal over an inferior metal is done in order to have attractive and beautiful appearance. e.g. Ornaments, Picture frames and luxury articles are electroplated by Silver, gold, nickel & Chromium etc.

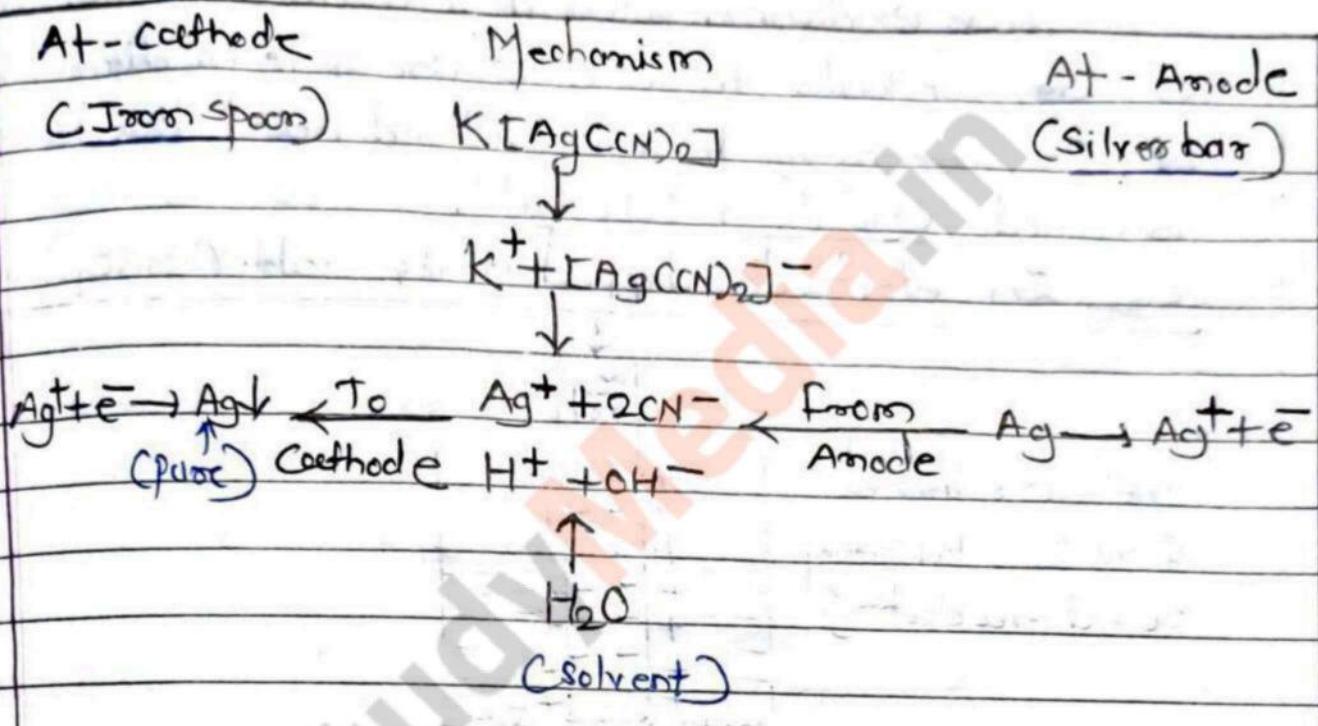
ii) Repairs \Rightarrow Broken pieces or worn part parts of machinery are repaired by electrodeposition of metal in between the broken or at the defective part of the metal.

iii) Protection \Rightarrow In order to save the latter (base metal) from rusting, corrosion of atmospheric action.

• Process:-

- i) The surface of the article ^(e.g. Iron spoon) to be electroplated is first cleaned thoroughly by using hot solution of alkali or soap to remove the grease (oily sub.) and Then it is treated with dil. acid to remove the impurities stick up to the article. It is called as 'pickling'.
 - ii) The cleaned article is then kept in a tank of cathode by connecting it with the negative end of the battery.
 - iii) The coating metal (i.e. Silver bar) is made as Anode by connecting it with the positive pole of battery.
 - iv) On passing electric current into the electrolytic soln., the Ag^+ ions from the electrolyte get deposited on the Iron spoon i.e. on cathode (i.e. the Iron spoon) ^{with a smooth & bright deposits of silver}.
 - v) The equivalent amount of anode i.e. Silver bar gets dissolved in the form of Ag^+ ions and passes into the electrolyte.
 - vi) The quantity of deposition (i.e. smooth & bright) depends upon the temperature, pH and conc. of the electrolytic soln.
 - vii) In case of Silver plating, electrolyte will be Potassium argentocyanide $\text{K}[\text{Ag}(\text{CN})_2]$. In case of silver plating, on passing the electric current, the Iron spoon (cathode) gets plated. Silver bar (Anode) gets slowly dissolved in solution and gives Ag^+ ions.
- Applications:-
- i) It is used to prepare decorative Articles, tableware, name plates, machine parts, mud guards, printed circuit boards, pens etc.
 - ii) Corrosion resistant coatings on steels, brass, aircraft parts etc. are made by using this process.

• Schematic Representation:-



• Net Result of Electrolysis :-

- The total no. of Ag^+ ions formed from Anode of electrolyte soln. are discharged at the surface of iron spoon i.e. Cathode; i.e. Silver gets deposited on the Iron spoon.
- The more active K^+ ion & H^+ ion remains in the soln. as they require very high voltage to discharge.

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