

Corrosion

Theories of Corrosion
 Factors Influencing Corrosion
 Types of Corrosion
 Prevention and Control of Corrosion

Metals spontaneously undergo gradual destruction when exposed to the atmosphere. In chemical terminology, such destruction is known as corrosion.

Corrosion is defined as the reaction of a metallic material with its environment, which causes a measurable change to the material and can result in a functional failure of the metallic component or of a complete system.

Exposure of the surface to air, water and caustic chemicals are responsible for corrosion. Since metals are good conductors, they undergo electrochemical changes on their surfaces. The compound that is formed during corrosion is referred to as *corrosion product* and the metal surface is said to be *corroded*. The *corrosion media* are generally liquids (mostly aqueous solutions), but also solids and gases.

The surface changes due to corrosion are carried through the equipment and destroy the performance and fabrication in due course. Some times, the leached metal may contaminate the product. The material of construction must be resistant to corrosion and erosion. Hence, adequate attention should be paid while selecting the materials for construction of equipment.

Corrosion can be either dry or wet type.

Dry corrosion : It involves the direct attack of dry gases (air and oxygen) on the metals through chemical reactions. As a result an oxide layer is formed over the surface. This type of corrosion is not common.

Wet corrosion : It involves the direct attack of aqueous media (strong or dilute, acidic or alkaline) on metal through electrochemical

reactions. The moisture and oxygen are also responsible. This type of corrosion is quite common.

Applications

Knowledge of corrosion is helpful in certain areas to prevent problems.

Dies and punches : In the compression of tablets, dies and punches should be free from rust and corrosion. Chromium plated dies and punches are used, so that the problems such as pits and abrasion can be avoided.

Milling equipment : In these equipment, a perfect fit between the moving parts should be maintained for effective size reduction. Though corrosion does not effect the performance of the mill or product, surface imperfections do not facilitate proper cleaning of the equipment. Hence, the associated problems persist.

Chemical processing reactors : Diverse nature of solutions which come in contact with the reactor surface often lead to corrosion on account of corrosive media and environmental conditions.

Fermenters : Glass, glass-lined and stainless steel (S.S.) materials are used for the construction of the fermentors. During fermentation, the release of trace metals from the equipment may have deleterious effects on the enzyme system and metabolic pathways of the organisms. The possible corrosion aspects in fermentors are pits and crevices, which make it difficult to clean and remove the contamination. Most of the operations are conducted at normal temperatures and the pH of the media would be around neutral. Maintenance of hygiene, need for sterility and prevention of contamination are important considerations in the construction of fermenters.

Storage containers : Prolonged storage of reactive chemicals leads to corrosion of the containers.

This chapter highlights the general aspects of corrosion such as corrosive environments, principles, types of corrosion and measures to prevent corrosion.

THEORIES OF CORROSION

The metal surface undergoes an electrochemical reaction with the moisture and oxygen in the atmosphere. This theory is known as *electrochemical theory of corrosion*. The mechanism involves the formation of a galvanic cell (anodic and cathodic areas), by different metals (for example, Fe and Cu) or in different areas on the same piece of metal (for example, iron).

When galvanic cells are formed on different metals, the corrosion is known as *galvanic corrosion*. These reactions are illustrated using the metals in the presence of electrolyte solution such as hydrochloric acid.

Corrosion Reactions on Single Metal

Electrochemical reactions are illustrated by considering the corrosion on a piece of iron in hydrochloric acid. Anodic and cathodic areas are formed on the surface of iron, owing to surface imperfections (localised stresses, grain orientation, inclusions in the metals) or due to variations in the environment. Numerous tiny reactions may occur (Figure 16-1).

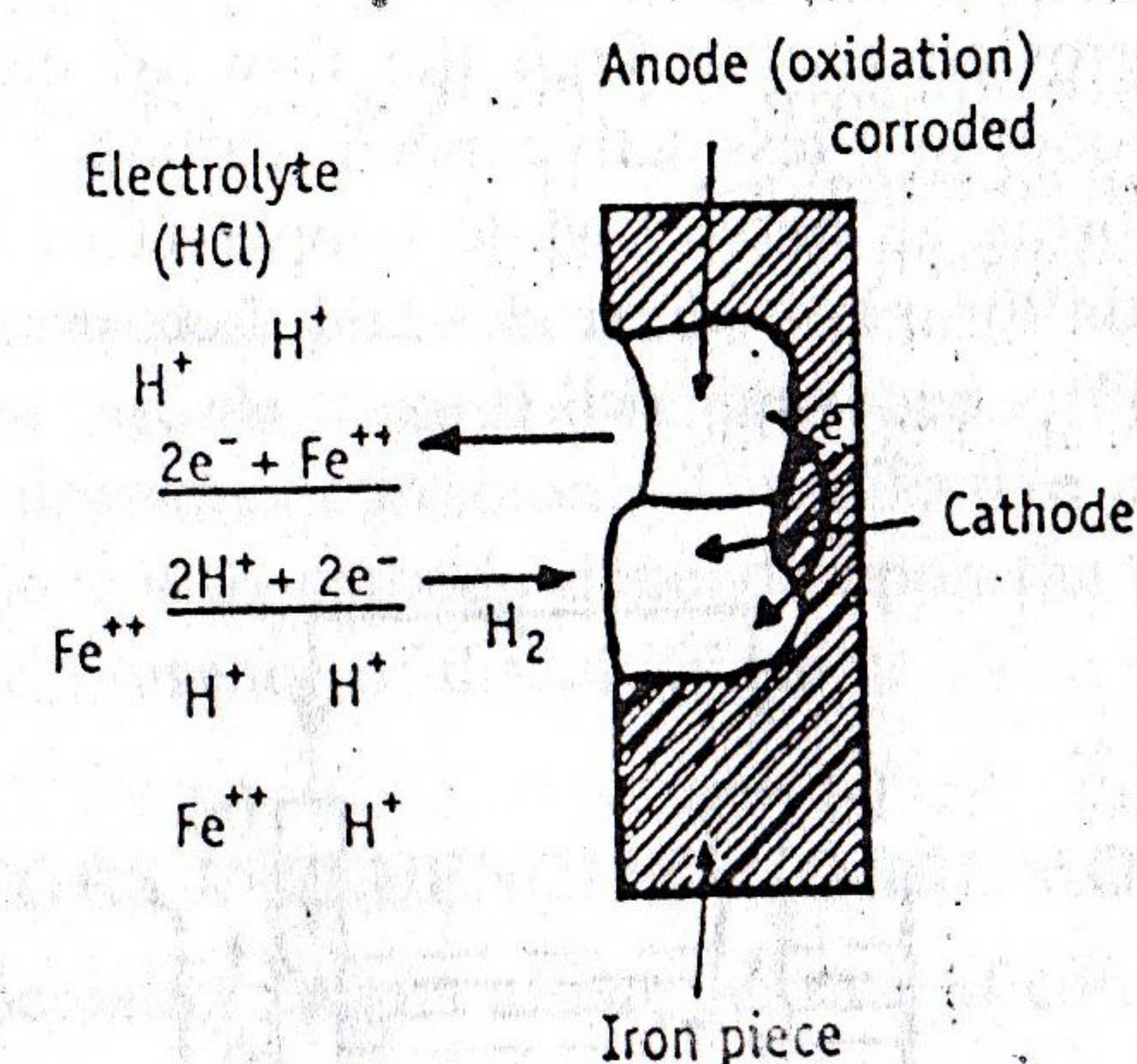


Figure 16-1. Electrochemical mechanism of corrosion. Different areas on the iron piece are illustrated.

Reaction at anode : Oxidation takes place with the release of electrons. Positively charged iron atoms get detached from the solid surface and enter into solution (electrolyte) as positive ions.

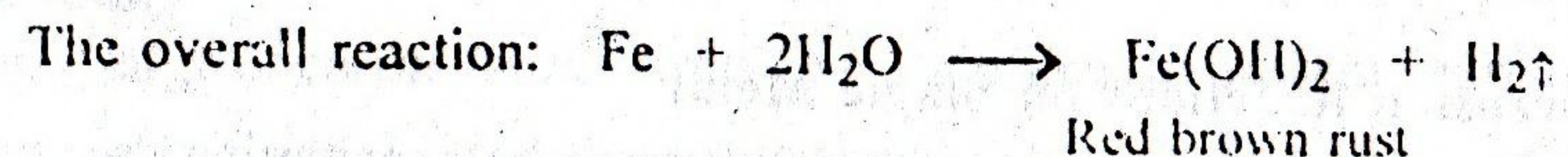
At anode: $\text{Fe} \longrightarrow \text{Fe}^{++} + 2\text{e}^-$ (indicated by rough surface)
(oxidation)

The released free electrons (negative charge) pass round the external circuit.

Reaction at cathode : Reduction of constituents occurs with the taking up of electrons. The free electrons reach the cathode and react with some positively charged species such as hydrogen ions in the electrolyte solution. In the absence of acid, water itself dissociates to generate H^+ ions.

At cathode: $2\text{H}^+ + 2\text{e}^- \longrightarrow \text{H}_2\uparrow$ (indicated by formation of bubbles at the surface)
(Reduction)

The amount of metal (iron) which is dissolved in the electrolyte is proportional to the number of electrons flowing, which in turn is dependent upon the potential and resistance of the metal.



High evolution of H_2 accompanies rapid corrosion such as hydrogen embrittlement. Depletion of hydrogen also enhances corrosion. In moderate concentrations of H_2 , corrosion slows down.

Corrosion Reactions Between Metals

Galvanic corrosion results from the flow of current from a more active metal (anode) to a less active metal (cathode). For example, zinc dissolves and forms an anode, while copper (Cu) forms the cathode. These two metals form two electrodes and their presence in an electrolytic solution forms a galvanic cell (Figure 16-2).

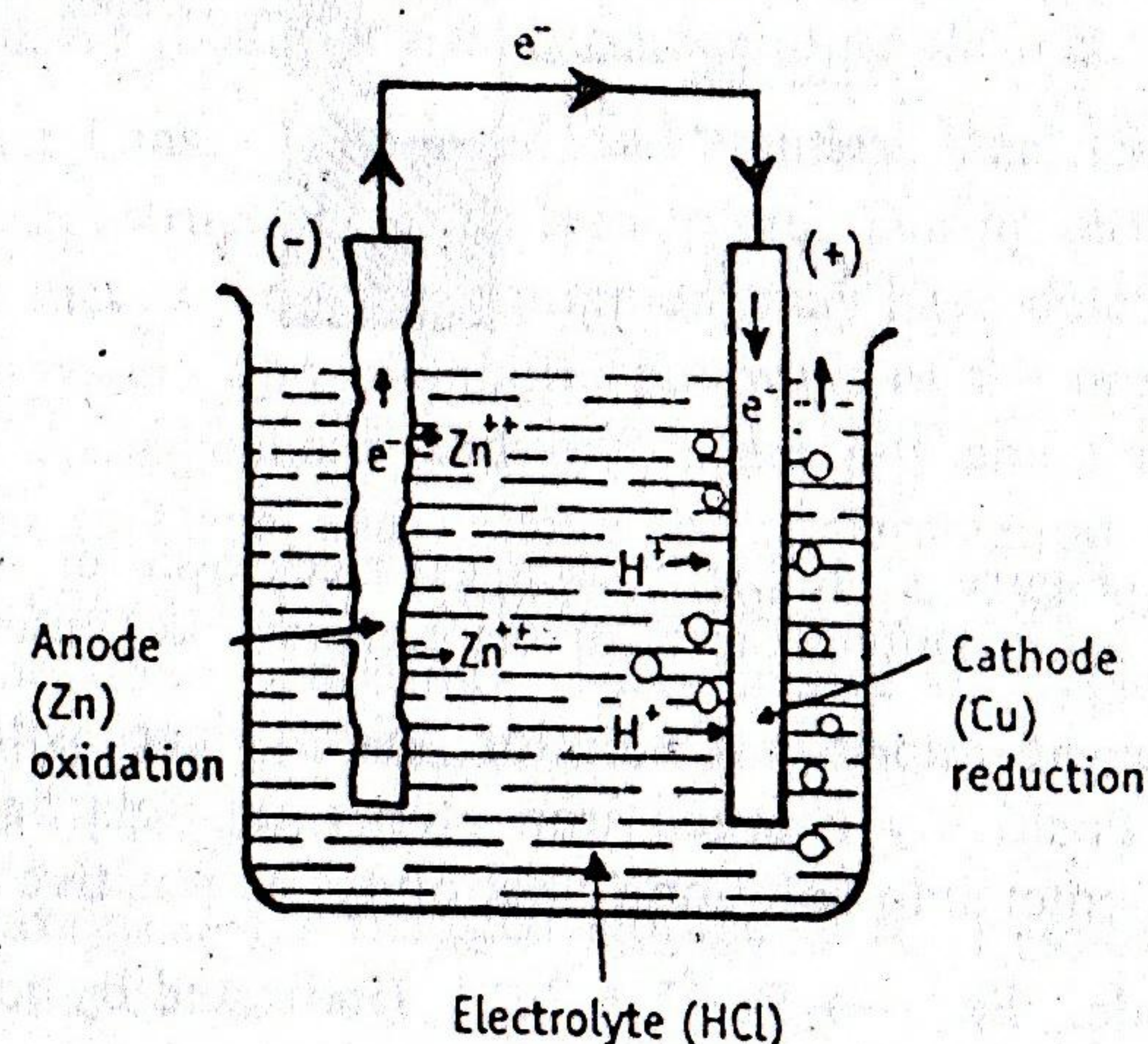
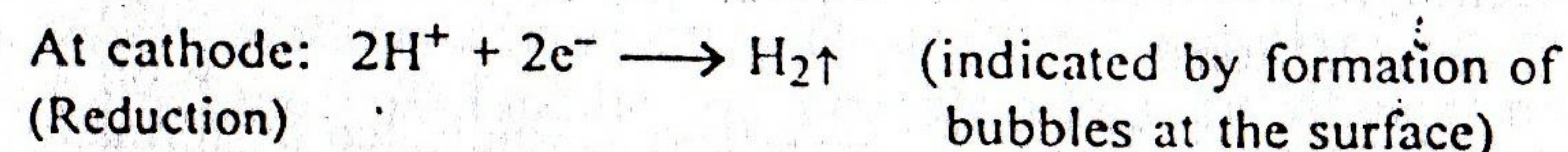
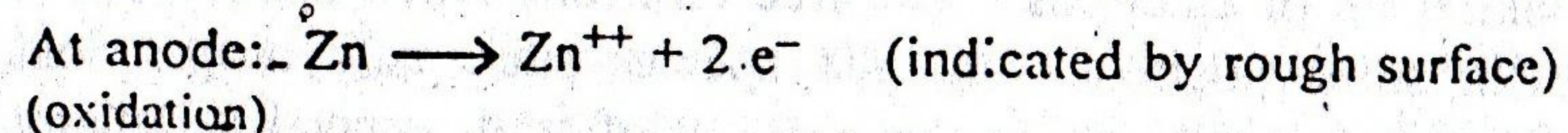


Figure 16-2. Galvanic mechanism of corrosion. Reactions between different kinds of metals.

Spontaneous reaction can occur when two electrodes are connected through an external wire. Reactions at anode and cathode are:

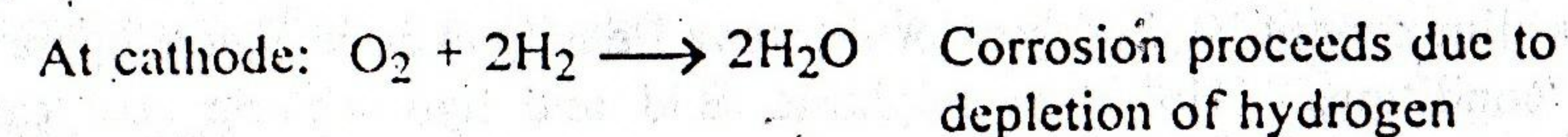


The corrosion current flows at the expense of the anode metal, which gets corroded continuously, whereas the cathode metal is protected.

In some cases, evolution of the hydrogen gas is slow. The accumulation of a layer of hydrogen on the cathode surface slows down the corrosion. This is called *cathodic polarisation*. It forms an insulating layer that slows down or stops the electrochemical reaction.

Corrosion Involving Oxygen

The oxygen dissolved in an electrolyte can react with accumulated hydrogen to form water. Depletion of hydrogen layer allows corrosion to proceed.



The above reaction takes place in acid media. When the corrosion media is alkaline or neutral, oxygen is absorbed. The presence of moisture (or water) promotes corrosion. The effective concentration of oxygen in water adjacent to cathode depends upon the degree of aeration, temperature and presence of dissolved salts.

FACTORS INFLUENCING CORROSION

A number of processing factors affect the rate of corrosion.

Solution pH

The pH affects the rate of corrosion of metals by one of the three general patterns.

- (1) Metals such as iron dissolve rapidly in acidic solution. In the middle pH range (4 to 10), the concentration of H^+ ions is low. Hence, the corrosion rate is controlled by the rate of transport of oxidizer (oxygen).
- (2) Certain amphoteric metals dissolve rapidly in either acidic or basic solutions. Examples are aluminium and zinc. Corrosion proceeds.
- (3) Noble metals are not affected by pH. Examples are gold and platinum.

The H^+ ions have a tendency to take up electrons to form H_2 gas. Therefore, H^+ ions capture electrons and promote anodic corrosion.

Oxidising Agents

Oxidising agents may accelerate the corrosion of one class of materi-

als, whereas retard another class.

Oxidizing agents such as oxygen (O_2) react with hydrogen to form water. Once hydrogen is removed, corrosion is accelerated. For example, copper in sodium chloride solution follows this mechanism.

Oxidising agents retard corrosion due to formation of surface oxide films, which makes the surface more resistant to chemical attack. Therefore, adsorbed oxygen layer is essential. Thus a balance between the power of oxidising compounds to preserve the protective film and their tendency to destroy the protective film determine the corrosion of the metal. For example, an oxide film is rapidly formed on stainless steel. This film cannot be dissolved or destroyed easily even in severe operating conditions. However, sulphuric acid and hydrochloric acid can easily destroy this oxide film.

Temperature

The rate of corrosion tends to increase with rising temperature. It has a secondary effect. The influence of temperature on corrosion may follow several of these mechanisms.

- (1) Increase in temperature reduces the solubility of oxygen or air. The released oxygen enhances the corrosion.
- (2) Increase in temperature induces phase changes, which enhances the rate of corrosion. At high temperatures, organic chemicals are saturated with water. As the temperature decreases, water gets condensed.
- (3) Oxygen is needed for maintaining iron oxide film, which prevents corrosion. In the absence of oxygen (due to increase in temperature), the corrosion of stainless steel increases.
- (4) Copper-based alloys do not depend on the oxide film for corrosion.

Velocity

When the corrosive medium moves at a high velocity along the metallic surface, the rate of corrosion frequently increases. High velocity has the following effects.

- (1) Corrosion products are formed rapidly, because chemicals (including oxidising substances) are brought to the corroding surface at a higher rate.

- (2) The accumulation of insoluble film on the metallic surface is prevented. Therefore, corrosion resistance of these films decreases.
- (3) The corrosion products (or film) are easily stifled and carried away, thereby exposing the new surfaces for corrosion.

Thus corrosion proceeds unhindered. This factor is responsible for the corrosion of a number of equipment parts, such as condensers, evaporator pipes (in the vicinity of bends in the pipes), propellers, agitators and centrifugal pumps. Corrosion occurs frequently in small diameter tubes/pipes through which corrosive liquid may be circulated at high speeds as shown in the above examples.

Surface Films

Once corrosion is started, its further progress is often controlled by the nature of surface films. A variety of surface films have been observed.

Thin oxide films are formed on the surface of stainless steel (rusting). These films tend to retain or absorb moisture, which delays the time of drying. Hence, the surface exposure to atmosphere or corrosive vapour increases the extent of corrosion. The rust films formed on low alloy steels are more protective than those formed on unalloyed steel.

Insoluble salts such as carbonates and sulphates may be precipitated from hot solutions on the metal surfaces. These protect the metal surfaces.

If the film is porous (example is zinc oxide), corrosion continues. Nonporous films (example is chromium oxide film on iron) prevent further corrosion.

Oil and grease films may occur on the surfaces either intentionally or naturally. These films protect the surface from direct contact with corrosive substances. Examples are metals submerged in sewage or equipment used for processing oily substances.

Other Factors

The concentration of corrosive chemicals in the environment influences the rate of corrosion. In equipment such as distillation columns, reactors and evaporators, the concentration can change continuously, making prediction of corrosion rate difficult. In addition, corrosion rates are seldom linear over a wide range. Concentration is important during plant shut-down. The presence of moisture that collects during cooling

TYPES OF CORROSION

Pure metals and their alloys tend to enter into chemical union with the components of a corrosive medium to form stable compounds. Corrosion can be broadly classified as follows.

1. Fluid corrosion, General
2. Fluid corrosion, Localised
3. Fluid corrosion, Structural
4. Fluid corrosion, Biological

Fluid Corrosion : General

When corrosion is generally confined to a metal surface, it is known as *general corrosion*. This type occurs in a uniform fashion over the entire exposed surface area at a wide range of temperatures. General corrosion is of two types.

Physicochemical corrosion : The effects of this type are swelling, crazing, cracking, softening etc. Examples are plastics and nonmetallic material.

Fluid Corrosion, Localised

Specific site corrosion

- Intergranular corrosion
- Pitting corrosion
- Crevice corrosion

Stress induced corrosion

- Stress corrosion cracking
- Corrosion fatigue
- Fretting corrosion

Liquid flow related corrosion

- Erosion
- Impingement attack
- Cavitation erosion

Chemical reaction related corrosion

- Galvanic corrosion
- Oxygen concentration cells
- Hydrogen embrittlement

Figure 16-3. Classification of localised fluid corrosion

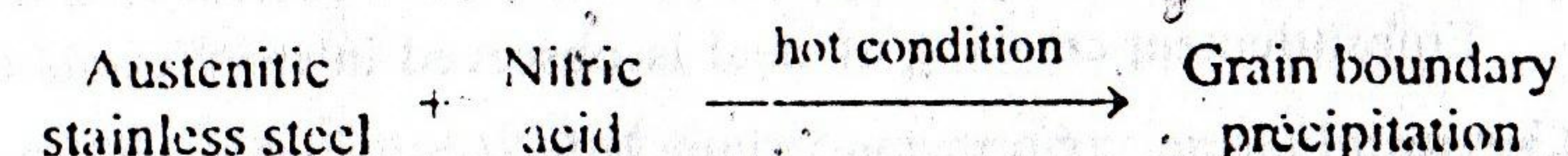
Electrochemical corrosion : This type of corrosion occurs at discrete points of metallic surfaces when electricity flows from cathodic area to anodic area. Metallic surface gets divided into anodic portion or cathodic portion.

Fluid Corrosion : Localised

Fluid corrosion is the most frequently observed on different locations in a material. It occurs in numerous ways. It is further classified as given in Figure 16-3.

Specific site corrosion : Mechanically weak spots or dead spots in a reaction vessel cause specific site corrosion.

Inter-granular corrosion : Selective corrosion that occurs in the grain boundaries in a metal/alloy is called as *intergranular corrosion*. Microscopic examination can reveal clearly the intergranular corrosion. When severe, this attack causes a loss of strength and ductility out of proportion to the amount of metal actually destroyed by corrosion. Crystalline grain structure as such is not attacked appreciably. One example is:



Stainless steel is stabilized by incorporation of niobium/titanium or carbon (less than 0.03%).

Pitting corrosion : This type of corrosion results in development of pits and cavities. They range from deep cavities of small diameter to shallow depressions. Example is:



Pitting of a metal occurs when there is a break in the protective oxide layer and imperfections on the underlying metal. Inhibitors are sometimes helpful in preventing pitting corrosion.

Crevice corrosion : In this type, corrosion occurs in crevices because solutions are retained at such places, which takes longer time to dry out. When this occurs, the intensity of attack is usually more severe than surrounding areas of the same surface. Crevices are formed because of the metal contact with another piece of the same or other metal or with a nonmetallic material. Corrosion in the crevices is due to a number of reasons as given below:

- Deficiency of oxygen.
- Acidity changes.
- Buildup of ions.
- Depletion of inhibitor.

Stress induced corrosion : Residual internal stress in the metal or external applied stress accelerates the corrosion. Residual internal stress is produced by:

- Deformation during fabrication.
- Unequal rate of cooling from high temperatures.
- Internal stress rearrangements involving volume changes.
- Stress induced by rivets, bolts and shrink fits.

Eliminating high stress areas prevents this type of corrosion. The external stress can be kept at minimum by employing suitable experimental conditions.

Stress corrosion cracking : At the surface, if the tensile stress is equal to or more than the yield stress, the surface develops cracks. This is known as *stress corrosion cracking*. Examples are:

- Cold-formed brass develops crack in the environment of ammonia.
- Embrittlement cracking of steel is observed in caustic solution.

Corrosion fatigue : Corrosion fatigue is the ability of a metal surface to withstand repeated cycles of corrosion. The metal surface is stressed and simultaneously attacked by the corrosive media. Pits (concentration points) indicating corrosion are formed initially, which further develop into cracks. As this process continues, the surface loses its fatigue resistance and ultimate failure of equipment.

The protective surface oxide film reduces corrosion. Under cyclic or repeated stress conditions, rupture of protective oxide films takes place at a higher rate than at which new protective films can be formed. Therefore, the rate of corrosion is enhanced.

Fretting corrosion : Fretting corrosion occurs when metals slide over each other and cause mechanical damage to one or both. During relative movement of metals, two processes may occur, (i) frictional heat is generated, which oxidizes the metal to form oxide films (ii) removal of the protective films resulting in exposure of fresh surface to corrosion attack.

This can be avoided by using harder materials, minimising friction by lubrication or by proper designing of the equipment, so that no relative movement of parts takes place.

Flow related corrosion : Liquid metals can cause corrosion. Usually the driving force is the tendency of the liquid to dissolve solids or penetrating the metal along the grain boundaries at places of wetting. Corrosion rate is enhanced at high temperatures. A few examples are:

- Mercury attack on aluminium alloys.
- Molten zinc on stainless steel.

Impingement corrosion : This is also referred to as *erosion-corrosion* or *velocity accelerated corrosion*. It is accelerated by removal of corrosive products (such as oxide films), which would otherwise tend to stifle the corrosion reaction.

Erosion : Erosion is the destruction of a metal by abrasion and attrition caused by the flow of liquid/gas (with or without suspended solids). The additional factors that can influence erosion include:

- Alloy contents of the steel (for example, chromium, copper, manganese etc.).
- Pipe system design and component geometry.
- Water and steam composition (especially pH and oxygen content).

The use of harder metals and changes in velocity or environment are used to prevent erosion.

Cavitation erosion : Formation of transient voids or vacuum bubbles in a liquid stream passing over a surface is known as *cavitation*. The bubbles may collapse on the metal surface thereby causing severe impact or explosive effect. Therefore, considerable damage and corrosion is observed. The protective films also get destroyed due to impact.

Cavitation erosion is observed around propellers, rudders in pumps etc. Redesign, use of a more resistant metal and protective coatings are required to avoid this type of corrosion.

Chemical reaction related corrosion : Corrosion involves chemical reactions such as oxidation and reduction at anode and cathode, respectively.

Galvanic corrosion : Galvanic corrosion is associated with the flow of current to a less-active metal (copper cathode) from a more-active metal (zinc anode) in the same environment. Coupling of two metals, which are widely separated in the electrochemical series, generally produces an accelerated attack on the more active metal, zinc, i.e., anodic corrosion. Therefore, a combination of metals which are as close as possible in the electrochemical series should be chosen.

In galvanic corrosion, the effect of area is very important. For example, steel rivets on copper (Cu) plates will corrode much more rapidly than a steel plate with copper rivets. Corrosion at the anode may be 100 to 1000 times higher, if the two areas are same.

Protective oxide films tend to reduce galvanic corrosion. Insulating materials can be placed between two metal faces to prevent corrosion. For example, plates when bolted together, specially designed plastic washers can be used.

Oxygen concentration cell : This type of corrosion is due to the presence of oxygen electrolytic cell, i.e., a difference in the amount of oxygen in solution at one point exists when compared to another. Corrosion is accelerated where oxygen concentration is least, for example, under gaskets, stuffing boxes etc., because formation of an oxide film is not possible. This also occurs under solid substances that may be deposited on a metal surface as ready access to oxygen is shielded. Redesign/change in mechanical conditions must be used to overcome this situation.

Hydrogen embrittlement : Hydrogen can penetrate carbon steel and reacts with carbon to form methane. The removal of carbon results in decreased strength. Corrosion is possible at elevated temperatures as significant hydrogen partial pressure is generated. This causes a loss of ductility, (hydrogen embrittlement) and failure by cracking or blistering of the steel. Resistance to this type of attack is improved by alloying with chromium/molybdenum.

Hydrogen damage can also result from hydrogen generated by electrochemical corrosion reaction. The atomic hydrogen formed on the metal surface diffuses into the metal and forms molecular hydrogen at micro-voids. The result is failure by embrittlement, cracking and blistering. This phenomenon is observed in solution of specific weak acids such as hydrogen sulphide and hydrocyanic acid.

Fluid Corrosion : Structural

In structural fluid corrosion type, the structural (mechanical) strength is reduced on account of corrosion. This may occur when one component of the alloy is removed or released into the solution. The corrosion products may remain in the plant. Two examples are presented here.

Graphite corrosion : Graphite is an allotropy of carbon. Graphite corrosion occurs in gray cast iron. The metallic iron is converted into corrosive products leaving a residue of intact graphite mixed with iron

corrosive products and other insoluble constituents of cast iron. When the layer of graphite and corrosive products is impervious, corrosion will cease or slow down. If the layer is porous, the corrosion will progress by galvanic behaviour between graphite and iron.

When carbon steel is heated for prolonged periods at temperatures higher than 455°C, carbon may get segregated, which is then transformed into graphite. Hence, the structural strength of steel is affected. Employing killed steel or low alloyed steels of chromium and molybdenum or chromium and nickel can prevent this type of corrosion.

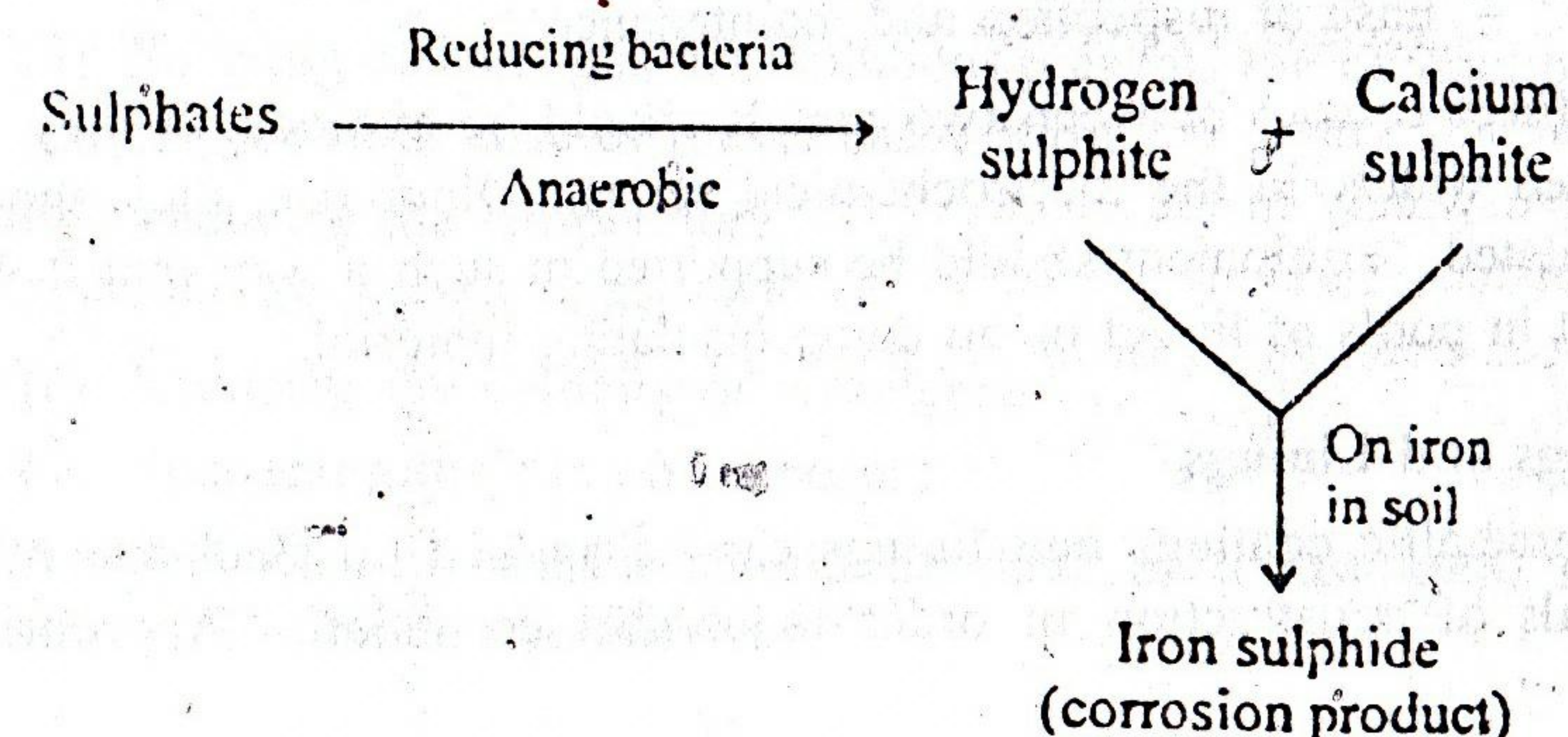
Dezincification : This type of corrosion is seen in brass that contains more than 15% zinc. In brass, the principal product of corrosion is metallic copper, which may redeposit on the plant. Another mechanism involves the formation of zinc corrosion products leaving the copper residue.

Corrosion may occur as plug filling pits (plug type) or as continuous layers surrounding the unaffected core of brass (general type). It can be reduced by the addition of small amount of arsenic, antimony or phosphorus to the alloy.

Fluid Corrosion : Biological

The metabolic action of microorganisms can either directly or indirectly cause deterioration of a metal. Such a process is called *biological corrosion*. Microorganisms associated with corrosion are either aerobic or anaerobic. The causes for biological corrosion are:

- (1) Producing corrosive environment or altering environmental composition.
- (2) Creating electrolyte-concentration cells on the metal surface.
- (3) Altering resistance to surface films.
- (4) Influencing the rate of anodic/cathodic reaction.



The role of biological corrosion may be explained using anaerobic sulphate reducing bacteria in slightly acidic or alkaline soils.

As these bacteria thrive under these conditions, they will continue to promote this reaction until failure of the pipe occurs.

PREVENTION AND CONTROL OF CORROSION

Selection of Proper Material

Corrosion should not be permitted in fine mesh wire-screens, orifices and other items in which dimensions are critical and changes are not permitted.

In many cases, non-metallic materials will be useful and attractive from the point of view of economics and performance. These should be considered if their strength, temperature and design specifications are satisfactory.

Permissible corrosion rates are important factors and differ with equipment. Appreciable corrosion can be permitted for tanks and lines, if anticipated and allowed for thickness in its design.

The corrosion characteristics of chemicals and limitations of construction materials must be considered from the literature before selecting equipment. In addition, processing conditions to which the material is exposed should also be considered. For this purpose, relevant literature should be consulted.

Proper Design of Equipment

In the design of equipment, a number of fittings such as baffles, stiffeners, drain nozzles, location of valves and pumps should be considered. Corrosion can be minimised, if the equipment design facilitates:

- Elimination of crevices
- Complete drainage of liquids
- Ease of cleaning
- Ease of inspection and maintenance

A direct contact between two metals should be avoided, if they are separated widely in the electrochemical series. Otherwise, they should be insulated. Equipment should be supported in such a way that it will not rest in pools of liquid or on damp insulating material.

Coatings and Linings

Nonmetallic coatings and linings can be applied on steel and other materials of construction in order to combat corrosion. Appropriate

methods such as electroplating, cladding, organic coatings should be considered. The thickness of the linings is important (100 mils). Effective linings can be obtained by bonding directly to substrate metal or building multiple layers or lamination.

Organic coatings are used as linings in equipment such as tanks, piping, pumping lines and shipping containers. Some examples of the linings are:

- | | | |
|-----------|----------------|-----------|
| - Ceramic | - Carbon brick | - Plastic |
| - Elastic | - Glass-coated | - Organic |

A thin non-reinforced paint-like coating of less than 0.75 mm thickness should not be used in services for which full protection is required from corrosion. Some examples of linings and uses are:

-
- | | |
|---------------------------------|-------------------------------|
| Tin coated steel (tin plate) | - food containers |
| Lead (Pb) coating (Terne plate) | - roofings |
| Aluminium (Al) coated steel | - high temp conditions |
| Zinc (Zn) coated steel | - many atmospheric conditions |
-

The cladding (i.e., mechanical bonding) of steel with an alloy is another approach to this problem. For instance, special glasses can be bonded to steel so that the liner is of 1.5 mm thick which is impervious. Equipment and pipings are lined in this manner and routinely used in severely corrosive acid services.

Altering Environment

Corrosion can be combated or reduced by employing the following environmental conditions.

- (1) Removing air from boiler feed water prevents the influence of water on steel.
- (2) Reducing aeration prevents the formation of passive oxide film in stainless steel alloys by acidic media.
- (3) Pumping of inert gas into solutions prevents the contact of air or oxygen as in case of nickel based alloys.
- (4) Reducing the temperature.
- (5) Eliminating the moisture.
- (6) Reducing the velocity or turbulence.
- (7) Shortening the time of exposure.

Addition of acid media should be done as a last step, so that maximum dilution can be obtained.

Inhibitors

The corrosion inhibitors are added to the environment to decrease corrosion of metals. These form protective films.

Adsorption type, for example, adsorbed on the metal.

Scavenger type, for example, remove corrosion agents.

Vapour phase type, for example, sublime and condense on metal surface.

Examples of inhibitors are given below.

Inhibitors	Material protected in the media
Chromates, phosphates, silicates	– iron and steel in aqueous solution.
Organic sulphides, amines	– iron and steel in acidic medium.
Copper sulphate	– stainless steel in hot diluted solution of sulphuric acid

Inhibitors are generally used in quantities less than 0.1% by weight. In some cases, the amount of inhibitor used is critical.

Cathodic Protection

The cathodic protection is based on the galvanic action between the metal(s) of the plant (cathode) and anode suspended in the solution. The metal to be protected is made a cathode, i.e., electrons are supplied, thereby dissolution of metal is suppressed. This can be achieved by two methods.

- (1) Sacrificial anode method
- (2) Impressed emf method

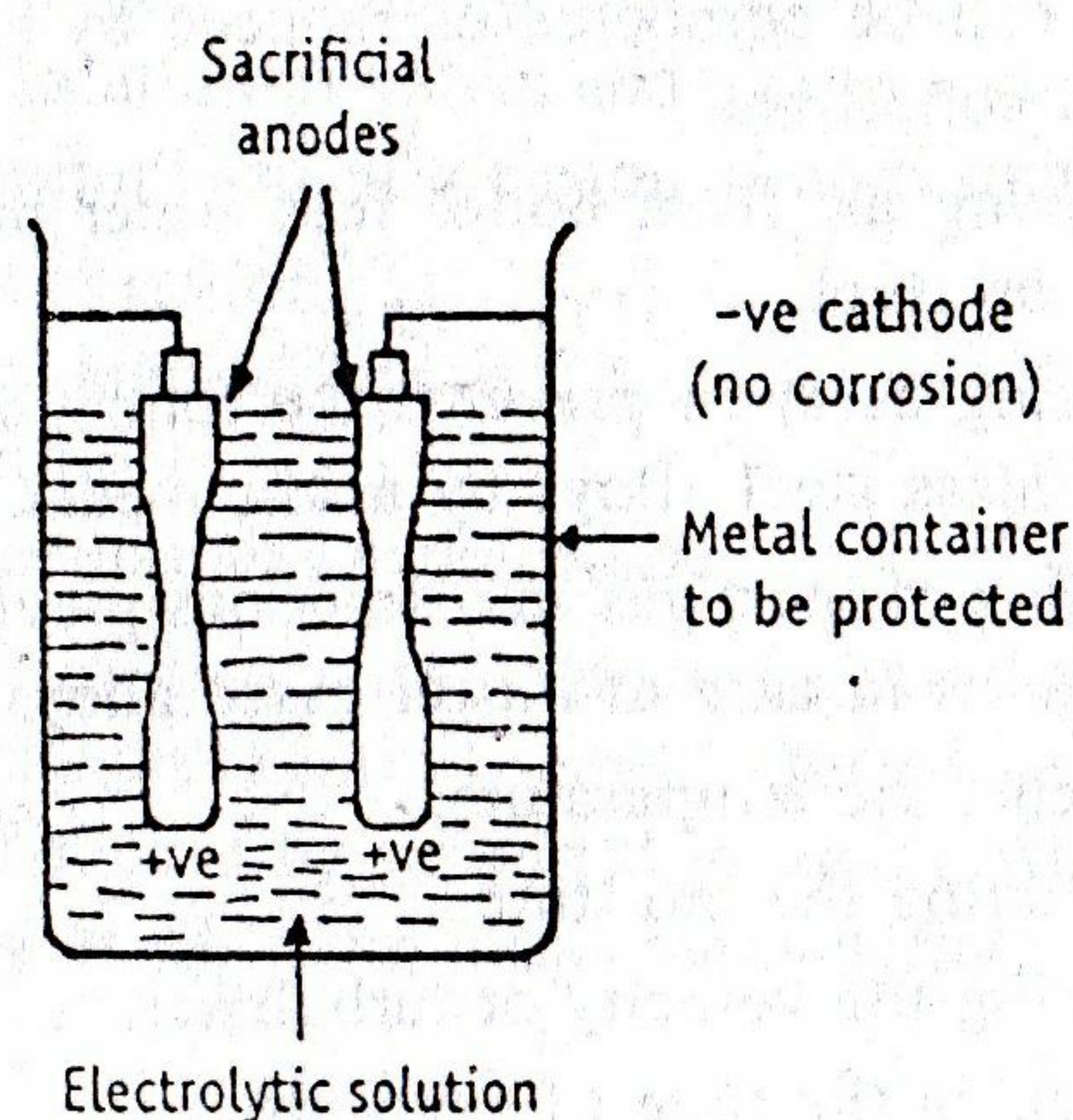


Figure 16-4. Simple sacrificial anodes.

Sacrificial anode method : In this method, anodes are kept in electrical contact with the metal to be protected (cathode). The anodes are sacrificed, since it goes into solution (Figure 16-4). For example, for the protection of iron and steel tanks, the metals such as zinc, aluminium, magnesium and their alloys are used as sacrificial anodes. These are used in limited pH range when high solution rate is acceptable, since these are amphoteric.

Anode metal is selected from the electrochemical series amongst the metals present below the tank metal. The anode should not be poisonous and not detrimental to the product.

Impressed emf Method : This is also known as *applied current system*, i.e., external voltage is impressed between tank and electrodes. The negative terminal of power supply is connected to the material to be protected. Therefore, the natural galvanic effect is avoided and the anode is maintained positive (Figure 16-5).

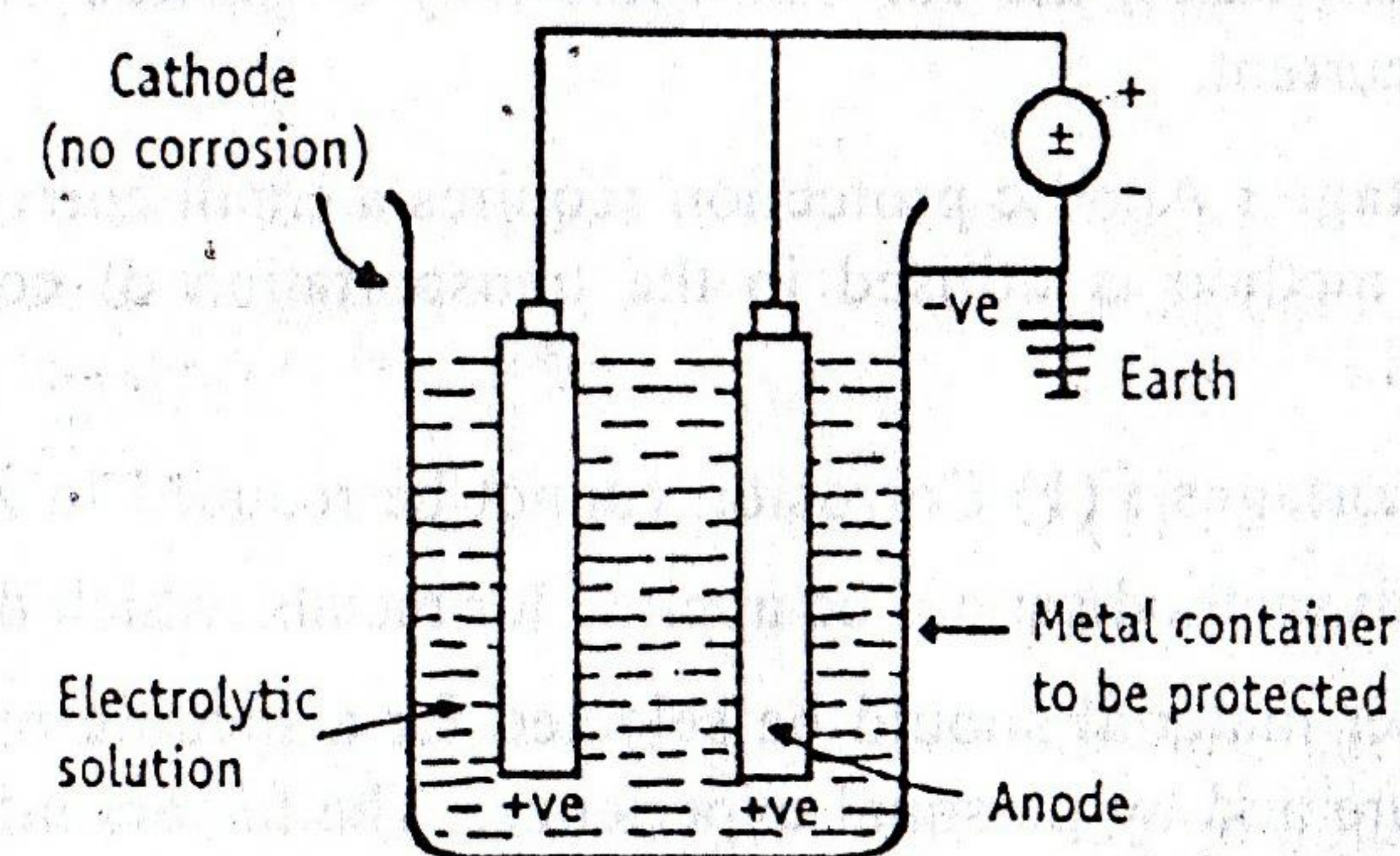


Figure 16-5. Impressed current cathode protection.

Since anode is not consumed, any conducting material, metal or non-corrodable alloys can be used. For example, in case of sulphuric acid and deionised water, graphite and high silicon steel are compressed. The anodes can be buried in the ground or suspended in the aqueous solution of electrolyte.

- Advantages :**
- (1) This method is used for large tanks to store mild corrosive liquors. In these cases, mild steel is used with negligible corrosion.
 - (2) Cathodic protection method is simple and the most effective.
 - (3) It is inexpensive. It enables the use of cheaper material for plant construction.

Disadvantage : Corrosion cannot be reduced to zero.

Anodic Protection

In the method, a predetermined potential is applied to the metal specimen and the corresponding current changes are observed. During the initial stage, the current increases indicating the dissolution (corrosion) of the metal. When the current reaches a critical point, passivation occurs, i.e., the oxide layer sets in a suitable oxidising environment. The potential at critical point is called *passivating potential*. Above this passivating potential, the current flow decreases to a very small value called passivating current.

The *passivating current* is defined as the minimum protective current density required to maintain passivation.

At this stage, an increase in potential will not corrode the metal since the latter is in a highly passive state. For example, in case of stainless steel, titanium becomes easily passive and cannot offer cathodic protection. In such cases, the corrosion rate may be slowed down by the use of anodic current.

Advantage : Anodic protection requires a small current. The anodic protection method is utilised in the transportation of concentrated sulphuric acid.

Disadvantages : (1) Corrosion cannot be reduced to zero.

(2) This method cannot be applied for metals, which do not passivate.

A proper material should be selected for a specific process based on the literature and by personal experience. The factors influencing corrosion will not only help in selecting the right kind of material, but also suggest the processing conditions. It is equally essential to identify the type of corrosion, if it occurs. Since the theories of corrosion are known, it is possible to adopt appropriate preventive measures.

QUESTION BANK

Each question carries 2 marks

1. Explain the terms 'pitting corrosion' and 'galvanic corrosion'.
2. Give the applications of protective linings and coatings with respect to corrosion control with suitable examples.
3. What is the role of plastic washers in the corrosion of metals?
4. How oxide films are formed? What are its advantages?
5. Highlight the role of oxygen in the corrosion of metals.

Each question carries 5 marks

1. What is corrosion? Mention the factors that influence rate of corrosion.
2. Explain measures you suggest to check the problems of corrosion.
3. Write electrochemical theory of corrosion.
4. Describe the biological corrosion and suggest the preventive measures.
5. Describe the mechanism of corrosion of iron.
6. Define corrosion. Give its causes. Classify corrosion.

Each question carries 10 marks

1. What is corrosion? Name the various types of corrosion. How can corrosion be prevented?
2. Discuss various types of corrosion and suggest the methods to tackle the same in pharmaceutical industries.