

Unit - III (1)
Corrosion & Control

CORROSION →

Metals have a natural tendency to revert back to combined states. During this process mostly, oxides are formed through in some cases sulphides, carbonates, sulphates etc. may results due to presence of impurities. Any process a deterioration & loss of solid metallic material by chemical or electrochemical attack by it's environment is called corrosion. Corrosion is the reverse process of metallurgy.



Types of Corrosion :-

Several types of corrosion occur -

DRY OR CHEMICAL CORROSION :-

This type of corrosion occurs mainly through the direct chemical action of atmospheric gases (O_2 , halogen, H_2S , SO_2 , N_2 or

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Dry or chemical corrosion :-

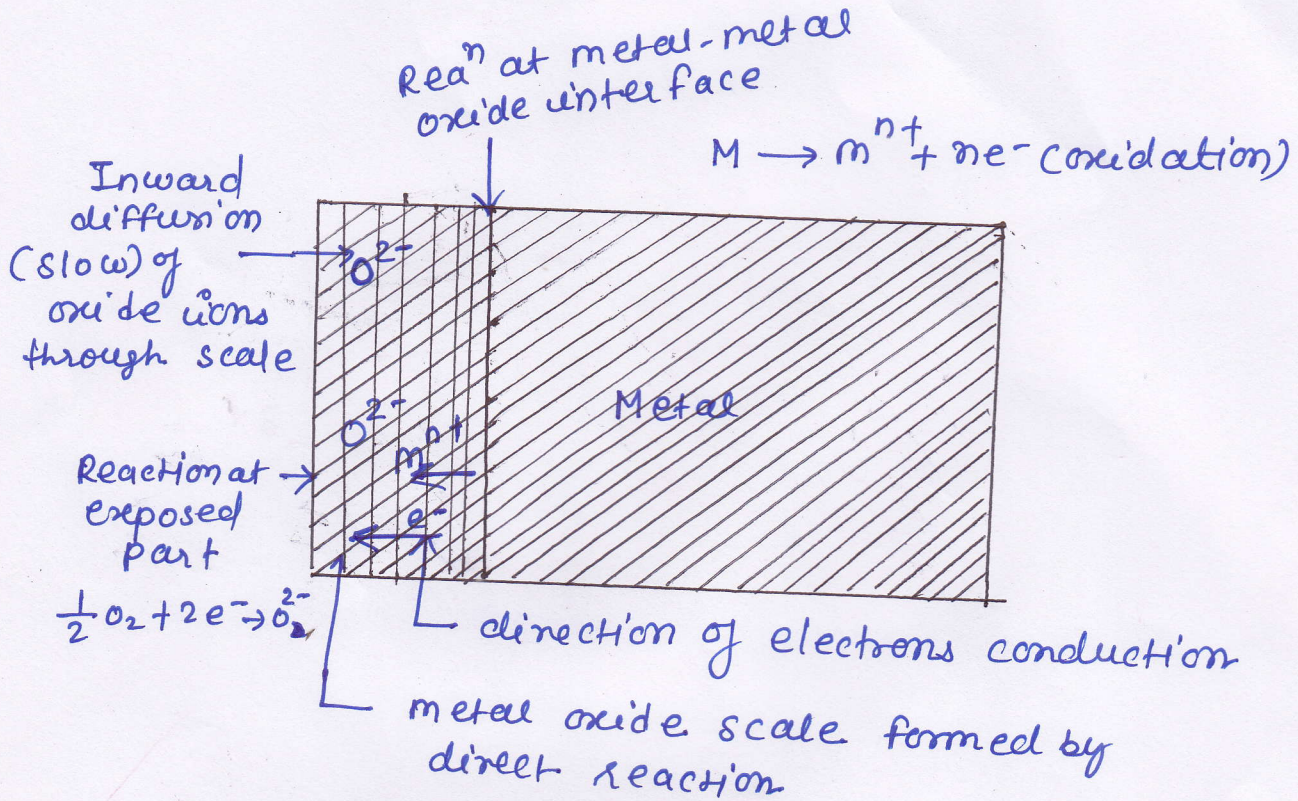


Fig → oxidation mechanism of metals

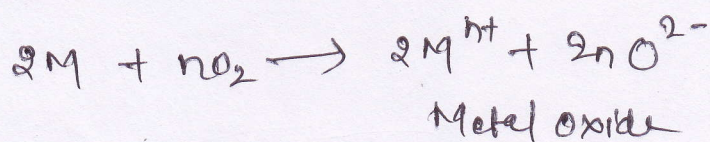
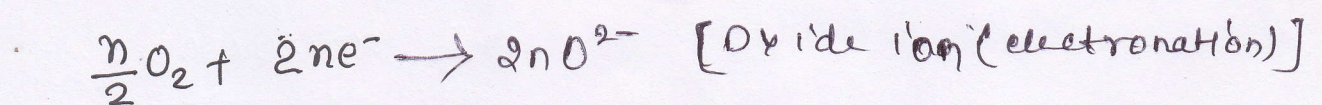
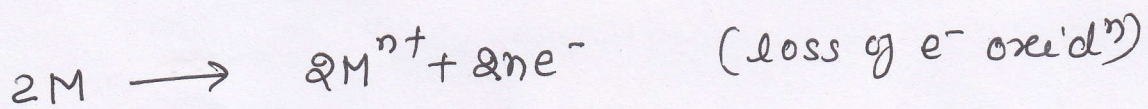
anhydrous inorganic liquid) with metal surface in immediate proximity. Three types of chemical corrosion are as follows -

a) Oxidation corrosion :-

This is carried out by the direct action of ~~hydrogen~~ oxygen at low or high temp. on metal in absence of moisture. At ordinary temp. metal are very slightly attacked.

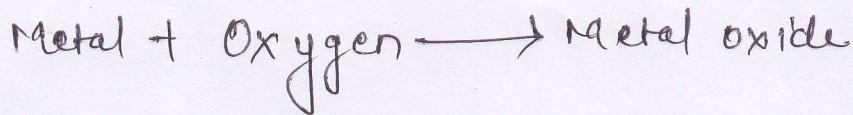
alkali metals (Li, K, Na, Rb etc) are oxidised rapidly at low temperature. At high temp. almost all metals (Except Au, Ag, & Pt) are oxidised.

The reaction in the oxidation corrosion are -



Mechanism :- At the surface of metal oxidation occurs and the resulting metal oxide scale forms a barrier which restricts further oxidation for oxidation. The metal must diffuse outwards.

through the scale to the ⁽⁴⁾ surface or the oxygen must diffuse inwards through the scale to the underlying metal. Both the cases are possible. But the outward diffusion of metal is generally more rapid than inward diffusion of oxygen.



when oxidation starts a thin layer of oxides is formed on the metal surface and the nature of this film decides further action

If the film is:

(a) stable; It behaves as a protective coating in nature.

(b) unstable, the oxide layer formed decomposes back into metal and oxygen.

(c) volatile, Oxide layer volatilizes after formation and as such leaves the metal surface exposed for further attack.

(d) corrosion by other gases ($\text{SO}_2, \text{CO}_2, \text{Cl}_2, \text{H}_2\text{S}, \text{F}_2$ etc)

The extent by corrosion depends of the chemical affinity between the metal and the gas involved. If the film formed is

(i) protective or non porous, The extent of corrosion decreases because the film protects the further

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(2) Non-protective or porous, the metal surface is attacked e.g. formation of volatile $SnCl_2$ by the attack of Cl_2 on Sn .

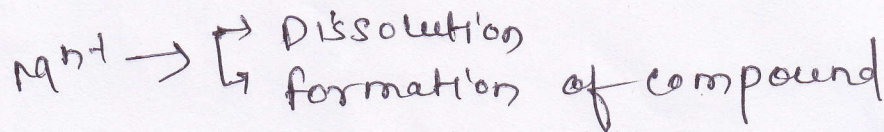
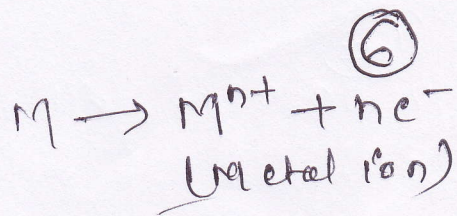
(3) Liquid metal corrosion, This is due to the chemical action of flowing liquid metal at high temperature on solid metal or alloy such corrosion occurs in devices used for nuclear power the corrosion reaction is carried out either by dissolution of a solid metal by liquid metal or by internal penetration of liquid metal into solid metal. The result is weakening of metal.

WET OR ELECTROCHEMICAL CORROSION :-

This type of corrosion occurs.

- (1) where a conduct liquid is in contact with the metal or
- (2) when two dissimilar metals or alloys are dipped partially in a solution.

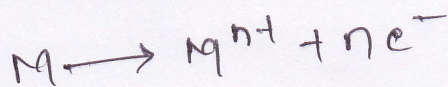
This corrosion occurs due to the existence of separate anodic and cathodic parts, between which current flows through the conducting solution. At anodic area, oxidation reaction occur there by destroying the anodic metal either by dissolution or formation of compound. Hence corrosion always at anodic



At cathodic part, reduction reaction occurs. It does not affect the cathode since most metals cannot be further reduced. The metallic ion formed at anodic part and the ions formed at cathodic part diffuse towards each other through conducting medium and form a corrosion product somewhere between anode and cathode.

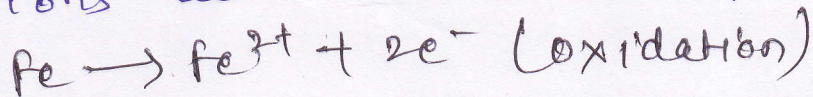
Mechanism:

Electrochemical corrosion involves flow of electrons between anode and cathode. The anodic reaction involves dissolution of metal liberating free electrons.

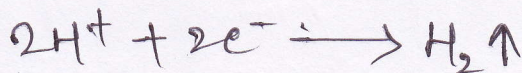


① Evolution of hydrogen:

This type of corrosion occur in acidic medium. e.g. considering the metal Fe anodic reaction is dissolution of iron as ferrous ions with liberation of electrons.



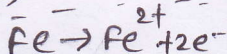
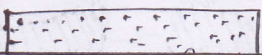
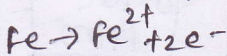
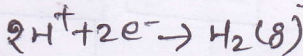
The electrons released flow through the metal from anode to cathode, where as H^+ ions of acidic solution are eliminated as hydrogen gas.



H⁺

Acidic solution
electrolyte

Cathodic
reaction

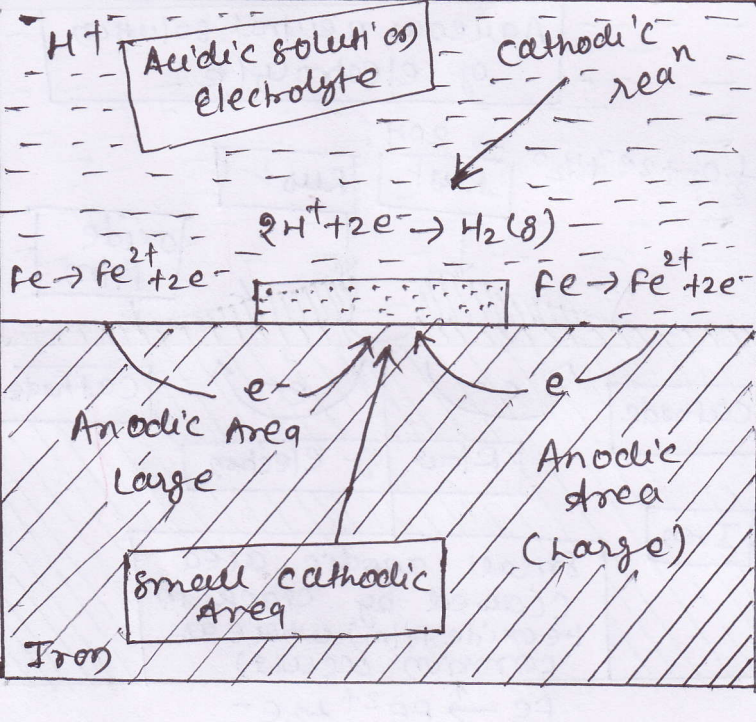


Anodic Area
Large

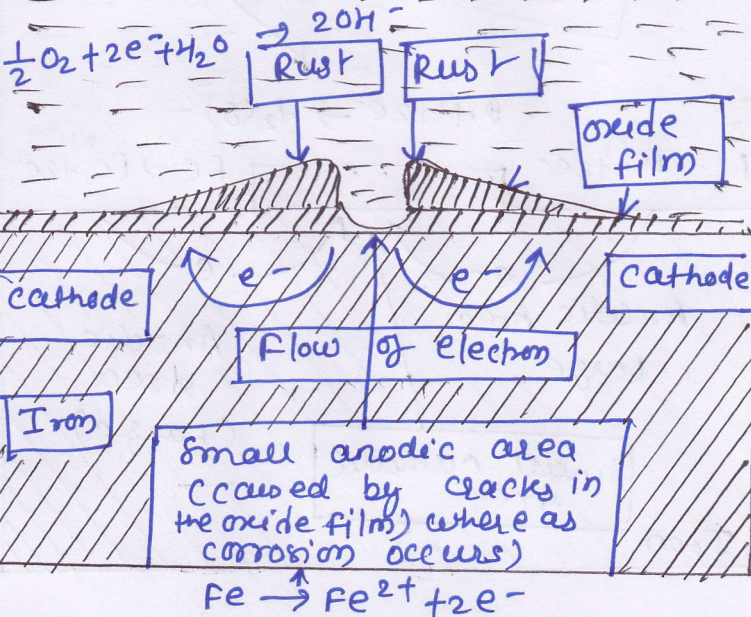
Anodic Area
(Large)

Small cathodic
Area

Iron



Aqueous neutral solution
of electrolyte



⑨

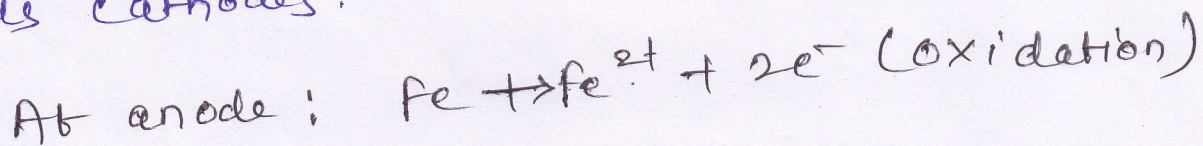
The over all reaction is



This type of corrosion causes displacement of hydrogen ion from the acidic solution by metal ions. All metals above hydrogen in electrochemical series have a tendency to get dissolved in acidic solution by evolution of H_2 or O_2 .

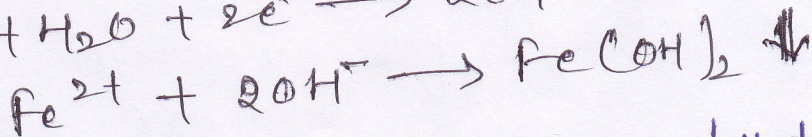
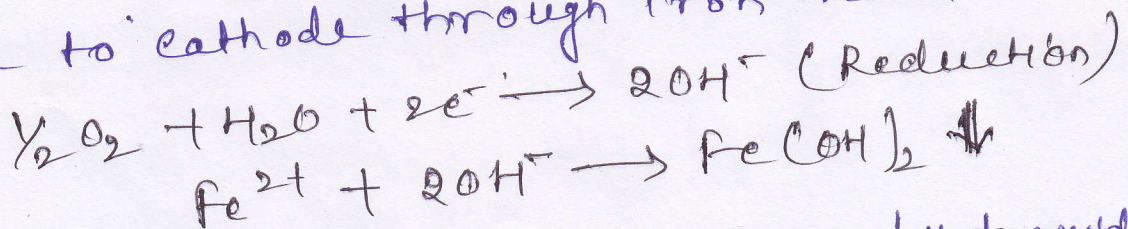
Absorption of Oxygen:

Rusting of iron in neutral or weak solution of electrolytes in presence of atmospheric oxygen. Usually the surface of iron is coated with a thin film of iron oxide. If the films develop cracks, anodic areas are created on the surface while the metal part act as cathodes.

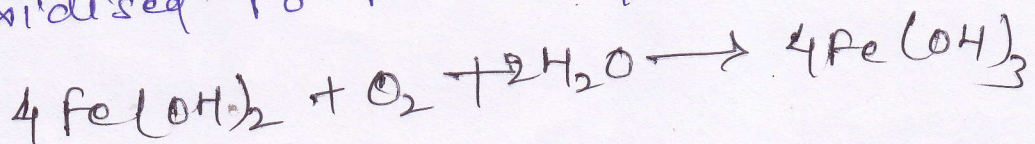


At cathode:

The released electrons flow from anode to cathode through iron metal.



(a) If oxygen is in excess, ferrous hydroxide is easily oxidised to ferric hydroxide.



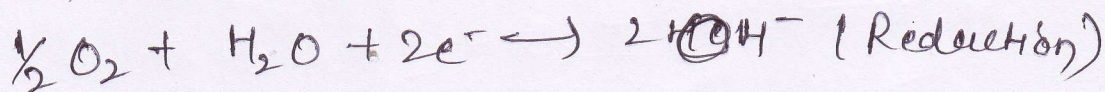
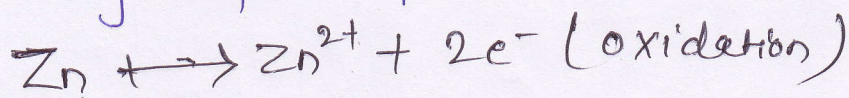
The product called yellow rust corresponds to $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$

(b) If supply of oxygen is limited, the corrosion product may be black anhydrous magnetite (Fe_3O_4)

CONCENTRATION CELL CORROSION :

This type of corrosion is due to electrochemical attack on the metal surface exposed to an atmosphere of varying concentrations or of varying aeration. The most common type of concentration cell corrosion is the differential aeration corrosion which occurs when one part of metal is exposed to different air concentration from other part. This causes a difference in potential between the differently aerated areas.

If a metal e.g. Zinc is partially immersed in a diluted solution of neutral salt. E.g. NaCl and the solution is not agitated properly, then the parts above and adjacent to the water line and strongly aerated and hence become cathodic whereas parts immersed show a smaller oxygen concentration and become anodic. So there is a difference of potential which causes flow of current between two differentially aerated areas of same metal. Zinc will dissolve at anodic areas and oxygen will take up electrons at the cathodic area forming hydroxyl ions.



Following are the facts about differential aeration corrosion.

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① less oxygenated part is the anode. Therefore cracks serve as foci for corrosion,

② Corrosion is accelerated under accumulation of dirt scale or other contaminations. This restricts the use of oxygen resulting an anode to promote greater accumulation. The result is localized corrosion,

③ metal exposed to aqueous media corrode under block of wood or glass which restrict the access of oxygen.

STRESS CORROSION

This is the combined effect of static tensile stresses and the corrosion environment on metal. Presence of tensile stress and a particular corrosive environment and necessary for stress corrosion to occur.

The corrosive agents are specified and selective like

- ① caustic alkalis and strong nitrated solution of mild steel,
- ② traces of ammonia for brass.
- ③ acid chloride solution for stainless steel.

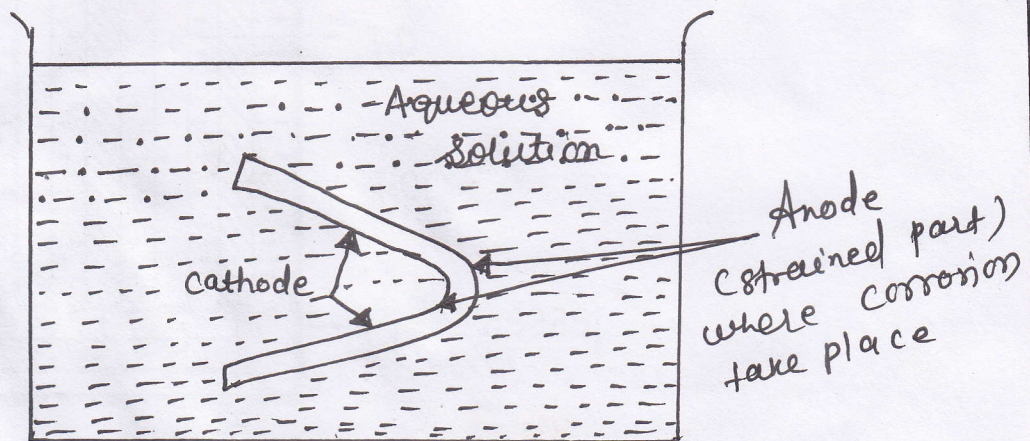
This type of corrosion is marked in fabricated articles of certain alloys due to stress cause by heavy working pure metals are resistant to stress corrosion. Stress causes strain which result in localized zones of high electrode potential. These become so chemically active that they are attacked even by a mild corrosive environment resulting a crack which grows.

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 salts or other contaminants. This restricts the
 use of oxygen resulting in anodes to promote anodic
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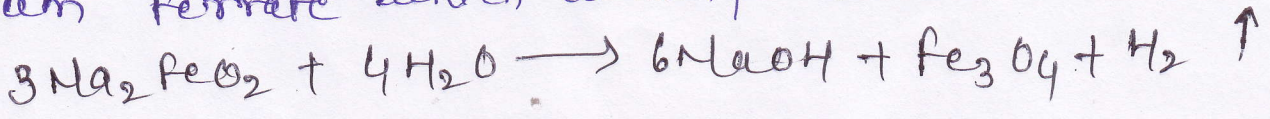
Examples:

① Season Cracking: This is the term applied to stress corrosion of copper alloys (brass). Pure copper is resistant to stress corrosion. Both Cu and Zn are electrochemically very active in ammonia solution due to formation of stable complex ions: $Cu(NH_3)_4^{2+}$ and $Zn(NH_4)$ respectively. This is the cause of dis-solution of brass which ultimately results cracks in presence of high tensile stress.

② Caustic embrittlement: This is the most dangerous form of stress corrosion occurring in mild steel exposed alkaline medium at high stress and temperature. This kind of corrosion occurs in steam boilers and heat transfer equipments in which water of high alkalinity attacks mild steel plates particularly at cracks. In high pressure boilers by using water softened with Na_2CO_3 this problem arises. Na_2CO_3 decomposes as



This causes boilers water caustic. This alkaline boiler water flows into crack where water evaporates increasing flow into hair-crack where water evaporates increasing concentrations of caustic soda. The concentrated alkali dissolves iron as sodium ferrate which decomposes as follows:



The regeneration of NaOH enhances further dissolution of iron. The iron surrounded by dilute NaOH is cathode while the iron in contact with concentrated caustic soda is anode part undergoing corrosion.

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Examples:

Reason for corrosion: This is the term applied to stress corrosion of copper alloys (brass). For copper is resistant to stress corrosion. Both Cu and Zn are electrochemically very active in ammonia solution due to formation of stable complex ions $Cu(NH_3)_2^{2+}$ and $Zn(NH_3)_4^{2+}$ respectively. This is the cause of stress corrosion of brass.

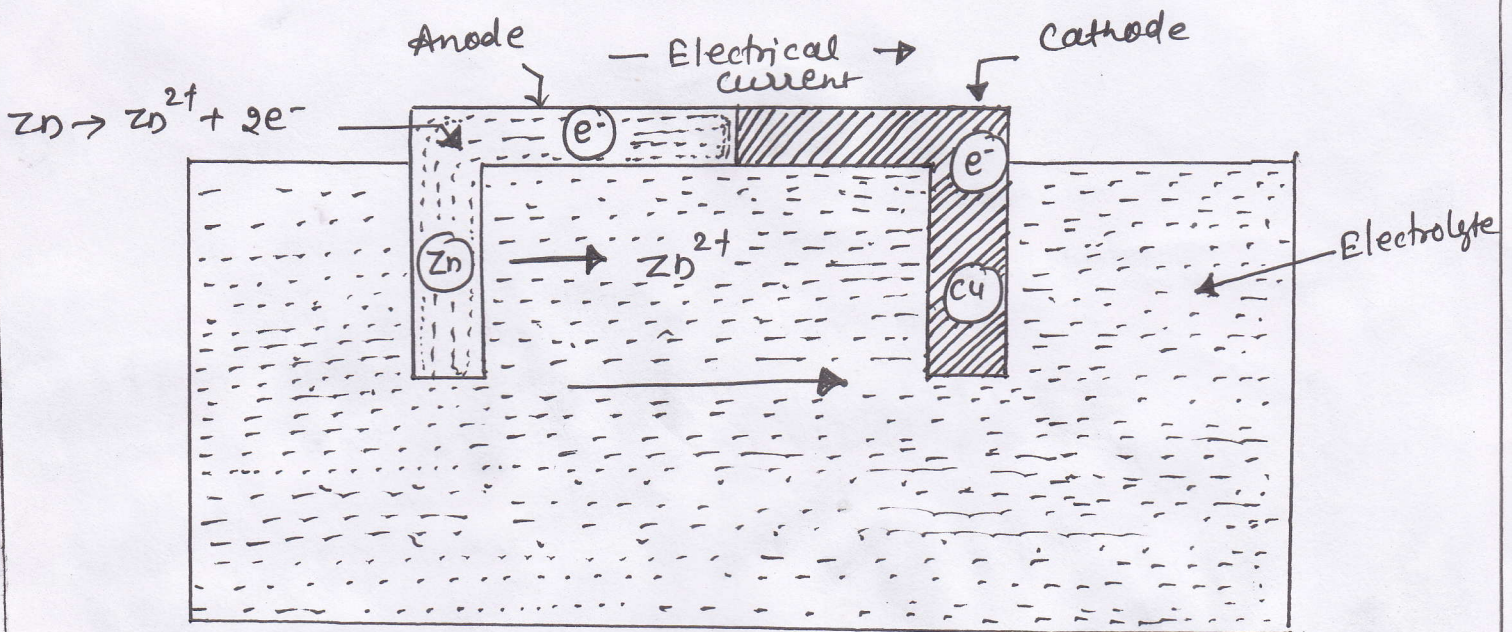


Fig- Galvanic Corrosion

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Prevention:

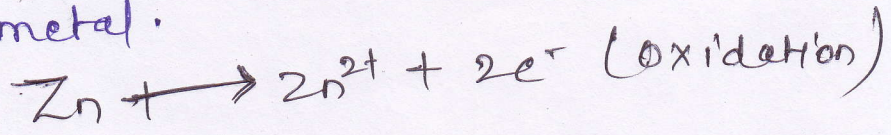
- ① By using sodium phosphate as softening agent instead of using sodium carbonate.
- ② Tannin or tannin is added to boiler water which blocks the hair cracks thereby preventing caustic soda solution to come in contact.
- ③ By adding Na_2SO_4 into boiler water which also blocks hair cracks.

GALVANIC CORROSION:

When two dissimilar metals are electrically connected and exposed to an electrolyte, the metal higher in electrochemical series undergoes corrosion is called Galvanic corrosion. eg. Zn form the anode and is attacked and get dissolved, where as copper act as cathode.

Mechanism:

If the solution is acidic then corrosion occurs by hydrogen evolution process and if the solution is neutral or slightly alkaline in nature the corrosion occurs by oxygen absorption process. The electrons flow from the anodic metal to the cathodic metal.



Thus corrosion occurs at anode at anode while cathode is not corroded.

- eg. ① steel pipe connected to copper plumbing.
 ② lead antimony solder around copper wire.

PITTING CORROSION

Pitting corrosion is a localized accelerated attack resulting in the formation of pits holes or cavities. Pitting corrosion therefore results in the formation of pinholes, pits and cavities in the metal. The pitting corrosion may be due to the following reasons:

- (a)
- (b) External environment is not homogenous.
- (c) Films are not perfectly uniform.
- (d) Crystallography directions are not equal in the reactivity.
- (e) Environment is not uniform with respect to concentration.

Pitting is usually the result of the breakdown or cracking of the protective film on a metal at specific points. eg. stainless steel and aluminium show

characteristic pitting in chloride solution. Pitting is caused by the presence of sand, dust, scale and other extraneous impurities present on the metal surface. Because of differential amount of oxygen in contact with the metal the small part become the anodic part and the surrounding large part become the cathodic areas. Intense corrosion take place in the anodic areas underneath the impurity. Once a small pit is generated, the rate of corrosion will be increased.



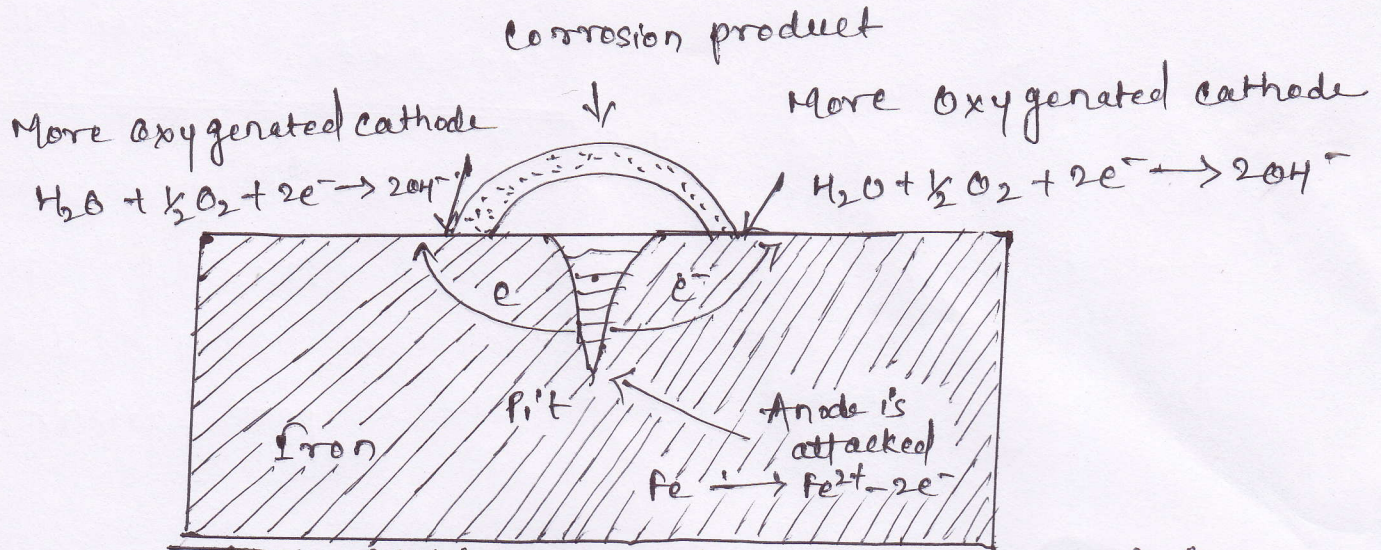


Fig: Pitting corrosion at the surface of iron

WATERLINE CORROSION :-

This is also known as differential oxygen concentration corrosion. In general, when water is stored in a steel tank, it's observed that the maximum amount of corrosion takes place along a line just beneath the level of the water meniscus. The area above the waterline act as cathodic and is not affected by corrosion. However, if the water is relatively free from acidity, little corrosion occurs. The problem of waterline corrosion a matter of concern for marine engineers - This type of corrosion is prevented to a great extent by painting the sides of the ship by antifouling paints.

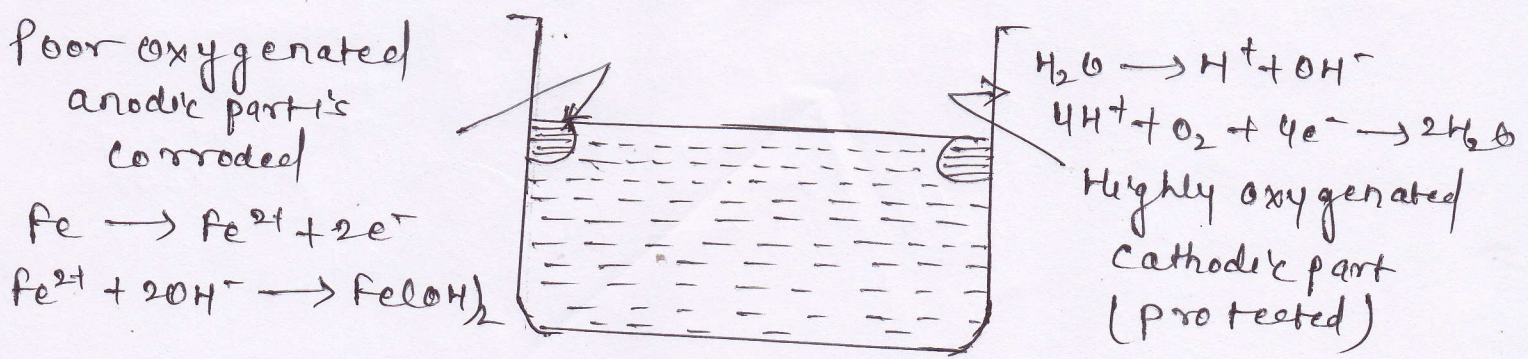


Fig:- waterline corrosion occurs just beneath the meniscus and the water level.

EROSION CORROSION:

Erosion corrosion result by the combined effect of the abrading action of vapours, gas and liquids and the mechanical rubbing action of solids over the surface of metals. This type of corrosion is caused by the breakdown of a protective film at the spot of impingement and its subsequent inability to repair itself under existing abrading conditions. The abrading actions remove protective film from localized spots on the metal surface, thereby resulting in the formation of different cells at the at such areas & to localized corrosion at anodic points of the cells. Erosion corrosion is most common in agitators, piping, condensers, tubes & vessels which steam of liquids or gases emerge from an opening & strike the side walls with his velocities.

Atmospheric corrosion →

This type corrosion is the result of conjoint action of oxygen & moisture. If one of these factors is missing, corrosion does not occur e.g. if iron is exposed to an atmosphere containing humidity more than 60%. rusting of iron starts & increase with increasing relative humidity. steel does not if covered with ice. This is only due to lack of water as electrochemical attack requires water

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increase of air is polluted by smoke. Some dust particles containing charcoal, which are capable of absorbing O_2 , solids particles of ammonium sulphate & industrial areas accelerate the corrosion process.

under ground corrosion or soil corrosion - the various factors responsible for corrosion are -

- i) Acidity of soil
- ii) Moisture content
- iii) content of electrolyte
- iv) Microorganism present
- v) content of organic matter
- vi) physical properties of soil.

soil contain large amount of organic matter, the action of solute metal complexes accelerate the corrosion. pipelines or cables passing from one to another type of soil, corrosion take place due to differential aeration. Air pockets in the soil cause corrosion due to differential aeration.

In a cable or pipe passes under a paving the portion under lying has less access to oxygen than one lying under paved soil. Hence the portion paving becomes oxide & sulphur corrosion.

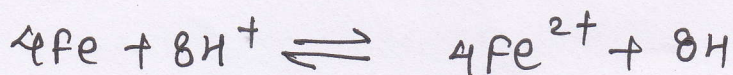
Microbiological corrosion :-

The result of the metabolic activity of various micro-organisms is called microbiological corrosion. The micro-organisms are either aerobic or anaerobic & develop in an environment with or without oxygen. Various micro-organisms responsible for corrosion because of their activity are -

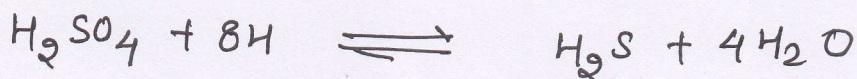
➤ sulphate reducing bacterias (Sproovobrio desulphuricus)

These are responsible for ~~aero~~ anaerobic corrosion of iron & steel. In addition to oxygen they need sufficient amounts of sulphates for their nourishment. Their growth is maximum b/w pH 5-9 & temp. of 20-30°. The mechanism of anaerobic microbiological corrosion of iron is →

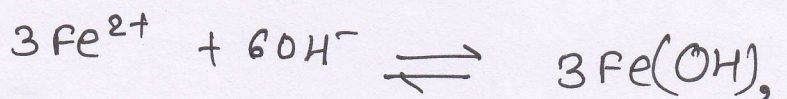
Anodic solution of iron -



Depolarisation due to activity of bacteria -



corrosion products →



a) Sulphur bacteria (Thioracillus) :-

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Microbiological Corrosion :-

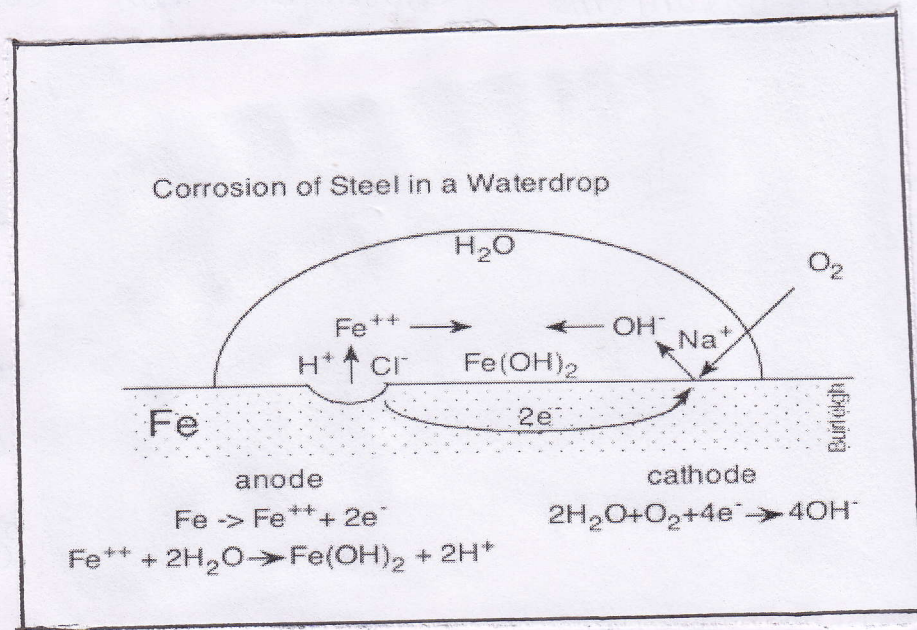


fig- Microbiological Corrosion

(Thioacetillus) are mostly aerobic & oxidise sulphur to yield sulphuric acid, which attacks the iron. Their growth is maximum in acidic medium (PH 0-1)

b) Film-forming microorganisms (bacteria, fungi, algae & diatoms) can form microbiological film on an iron surface. Such films are capable of maintaining concentration gradients of dissolved salts, acids & gases on the iron surface. This leads to the formation of local biological concentration cells & consequent corrosion.

Factors Influencing Corrosion :-

The rate & extent of corrosion depends on the nature of the metal & nature of corroding environment.

Nature of metal

i) position in galvanic series →

When two metal alloys are in electrical contact in presence of an electrolyte, the more active metal having higher position in the galvanic series undergoes corrosion. The greater is the difference in position, the faster is the corrosion.

ii) Overvoltage :- Reduction in overvoltage of the corroding metal accelerates the corrosion.

eg. Zn in $1N H_2SO_4$ undergoes corrosion slowly because of high overvoltage of zinc metal which reduces the effective potential to a small value. In presence of $CuSO_4$ the corrosion rate of Zn is accelerated.

iii) purity of metal \rightarrow Impurities in a metal generally cause heterogeneous state forming minute electro-chemical cells resulting corrosion of anodic part eg. Zn.

iv) Nature of film surface :- In aerated atmosphere all metal get covered with a thin surface of metal oxide. The ratio of the volumes of metal oxides to the metal is known as specific volume ratio greater its thin value lesser is the oxidation corrosion rate.

v) Solubility of corrosion product :-

In electrochemical corrosion if the corrosion product is soluble in the corroding medium then corrosion is rapid if the corrosion product is insoluble then acts as barrier thereby suppressing further corrosion.

Nature of corroding environment :-

i) Temperature \rightarrow As the temperature of environment is increased the reaction rate is increased

ii) Humidity of air :- Critical humidity is defined as the relative humidity above which the atmospheric corrosion rate of metal increase sharply. The value of critical humidity depends on nature of metal product & corrosion products.

Corrosion of a metal is faster in humid atmosphere because gases (CO_2 , O_2 etc) & vapours present in atmosphere furnish water to the electrolyte essential to establish an electrochemical corrosion cell.

Corrosion control → following are the methods for control of corrosion -

a) suitable designing :- The design of the material should be such that corrosion occurs in uniform & localized following principles are -

i) The contact of dissimilar metal in presence of corroding solution is to be avoided.

ii) The anodic materials should have as large area as possible when two dissimilar metal are in contact.

iii) When two dissimilar metal in contact have to be used they should be as close as possible in electrochemical series.

iv) Uniform flow of corrosive liquid is desirable.

- v) Insulating Pilling may be used to avoid direct metal-metal electrical contact.
- vi) The equipment should be supported on legs for free circulation of air.
- vii) The anodic metal should not be painted or coated because any break in coating would cause rapid localized corrosion.
- b) Using pure metal → Impurities in a metal causes heterogeneous state thereby accelerating corrosion rate. Corrosion resistance of a metal may be improved by increasing the purity. Corrosion resistance of a purified metal also depends on the nature of corroding environment.
- c) Cathodic protection → The metal to behave like cathode so that corrosion does not occur. Two types of cathodic protections are possible.
- d) Sacrificial protection → In this method the metal to be protected is connected by a wire to a more anodic metal. The more active metal losses e^- & get corroded slowly thereby protecting the parent cathodic metal. eg. galvanisation. Some sacrificial anodes are Mg, Zn, Al, etc.

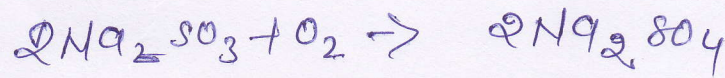
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 e) Electrical cathodic protection →

In this method impressed current is applied in opposite direction to nullify the corrosion current & convert the corroding metal from anode to cathode. The current is derived from direct source like battery or a.c. line with an insoluble anode.

iv) Modifying the environment → The rate of corrosion also depends on corroding envⁿ the corrosive nature of envⁿ can be reduced by,

a) Deaeration → Driving out dissolved oxys by adjustment of temperature with mechanical agitation

b) Deactivation → This involves addition of chemicals capable of combining with oxys in aqueous solution. eg.



c) Alkaline neutralization →

This is the prevention of corrosion by neutralizing the acidic characteristics of corrosive environment e.g. NH_3 , NaOH , lime etc. are alkaline neutralizers.

v) Use of inhibitors → A corrosive inhibitors is a substance which on addition in small quantity the aqueous corrosive envⁿ decreases the corrosion of a metal. Following are classification —

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A) Anodic inhibitors ⁽²⁷⁾ → These are absorbed on the metal surface forming a protective film thereby reducing the corrosion rate. Eg. Chromates

B) Cathodic inhibitors →
a) In acidic medium the reaction is evolution of hydrogen

$$2H^+ + 2e^- \longrightarrow H_2(g)$$

Corrosion may be reduced either by slowing down diffusion of hydrated H^+ ions to the cathode or increasing overvoltage of hydrogen evolution. The diffusion is decreased by organic inhibitors while antimony & arsenic oxide increase the hydrogen voltage.

b) In neutral & aqueous medium, the reaction is

$$H_2O + \frac{1}{2} O_2 + 2e^- \rightleftharpoons 2OH^-$$

The corrosion can be controlled either by elimination of oxygen from corroding medium or by retarding its diffusion to cathodic area. The former is attained by adding Na_2SO_3 or by deaeration.

vi) Organic coating → These are inert organic barriers applied on metallic surfaces for protection and also decoration. Organic coatings are two types -

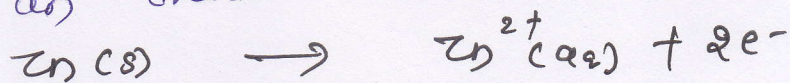
a) Those that protect the metal from corrosive atmosphere by forming an impervious film.

b) organic film which contains an inhibitor.

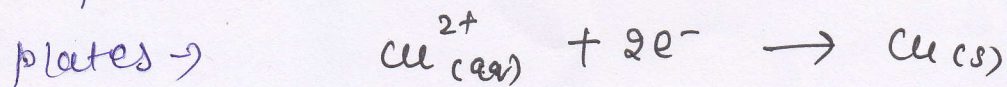
Galvanic cells

According to surface galvanic cell may be formed in several way. The principle of their working can be explained by considering a Daniel cell which consists of zinc & copper plates dipping in solution having Zn^{2+} ions & Cu^{2+} ions the solution being separated by a porous partition. The plates are connected by a metallic conductor. The emf developed is due to separate reactions taking place at the electrodes. Zn atoms have a tendency to go into solution as Zn^{2+} making two e^- available.

This is an oxidation reaction \rightarrow



The electrons move along the conductor & are responsible for the reduction reaction of the copper



Then the Zn dissolves & Cu is deposited at it's cost. Exactly similar reaction occurs in corrosion.

In this cell the Zn plate is called an anode because oxidation reaction, i.e. liberation of e^- takes place at the Zn plate.

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Similarly, because reduction reaction is consumption of electrons takes place at the copper plate the plate is called a cathode. The greater is the emf the faster will be corrosion.

When two dissimilar metals like Zn & Cu are electrically connected & exposed to an electrolyte the metal higher in electrochemical series undergoes corrosion. This type of ~~etc~~ corrosion is called galvanic corrosion. In the above example Zn higher in electrochemical series forms the anode & is attacked & gets dissolved whereas Cu lower in electrochemical series act as cathode.

Battery

Battery is a device which transforms chemical energy into electrical energy. The term battery is usually applied to a group of two or more electrical cells connected together electrically in series.

The batteries act as portable source of electrical energy. These are of two types.

- a) primary cells b) secondary cells

Commercial electrochemical cells

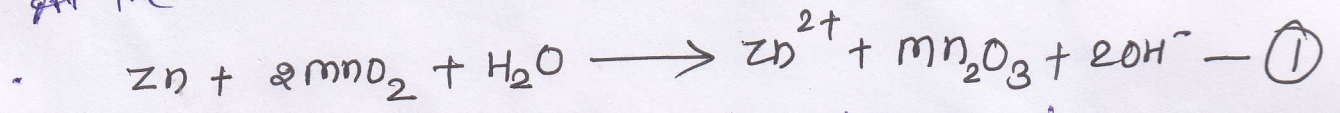
Primary cells	Secondary cell	Fuel cell
<p>1) Cell reaction is not reversible</p> <p>2) primary cell can not be recharged</p> <p>3) It is used in radio, calculators, etc.</p> <p>Ex → Leclanche/dry cell</p>	<p>1) Cell reaction can be reversed</p> <p>2) secondary cell can be recharged</p> <p>3. It is used in car battery, electronic calculators</p> <p>Ex → Lead storage cell</p>	<p>1) Energy can be withdrawn as long as the outside supply of fuel is maintained</p> <p>2) no such condition occur.</p> <p>3. It have great important in space vehicles & for astronauts.</p> <p>Ex → Hydrogen-oxygen fuel</p>

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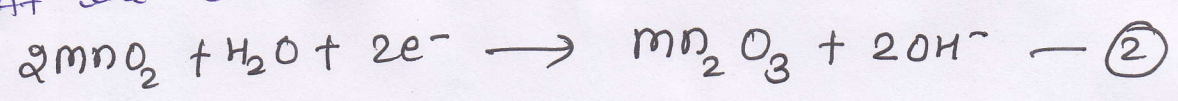
Leclanche or dry cell :-

It is primary cell in which a zinc plate is negative electrode & the carbon rod is the (+ve) electrode. The zinc plate usually forms the outer covering of the cell. The electrolyte is a paste of MnO_2 , NH_4Cl & $ZnCl_2$ & the space between the central carbon electrode & the zinc plate is completely filled with the paste.

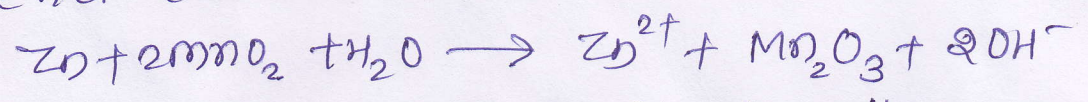
At the anode the oxidation process is -



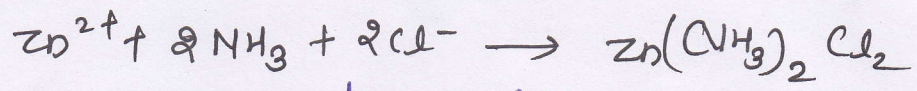
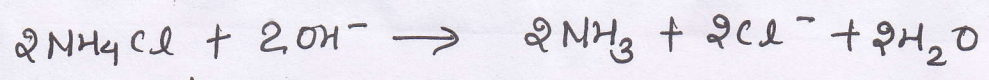
At the cathode the reduction process is,



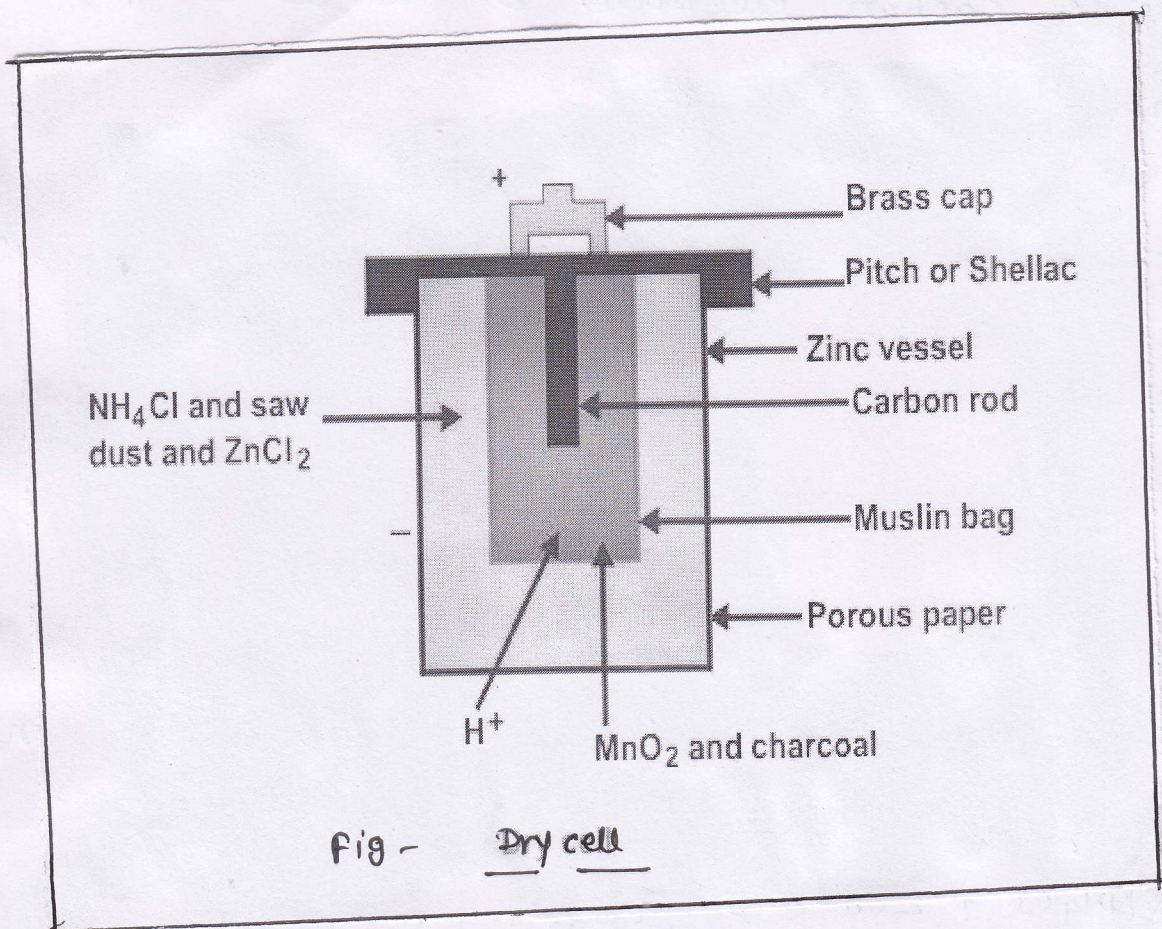
The net cell reaction is \rightarrow



The resulting OH^- ions react with NH_4Cl to liberate NH_3 which combines with Zn^{2+} ions to precipitate sparingly soluble $Zn(NH_3)_2Cl_2$



These are secondary reactions & are not involved in the electrode reaction. Hence they also do not contribute to the potential of the cell. The exhausted dry cell can't be brought back to original state. The emf of the cell depends upon the reaction (1) & (2) Dry cell is cheap to make & gives a voltage of about 1.5V.



Fuel cells → A fuel cell is an electrochemical cell which can convert the chemical energy contained in a readily available fuel oxidant system into electrical energy by an electrochemical process in which the fuel is oxidized at anode.

A fuel cell converts the chemical energy of the fuels directly into electricity.

Fuel + oxygen → oxidation product + Electricity

Types of fuel → on the basis of types of electrolyte used, fuel cells are of following types.

- a) Alkaline fuel cells.
- b) Hydrogen-oxygen fuel cells.
- c) Phosphoric acid fuel cells.
- d) Ion exchange membrane fuel cells. etc.

Principle & working of H₂-O₂ fuel cells →

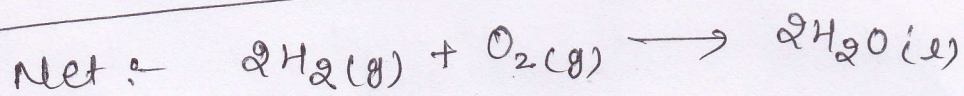
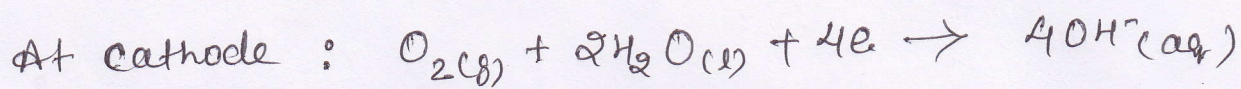
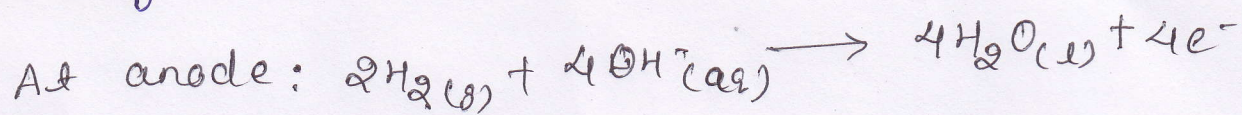
Hydrogen oxygen fuel cell was designed by (Bacon) & first demonstrated in the year 1959.

It consists of two inert porous electrodes & an electrolyte solution such as 25% NaOH / KOH solution. Both the electrodes are separated by a semipermeable membrane. Both the electrodes are placed in electrolytes.

During the generation of electricity

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Hydrogen & oxygen gases are bubbled through the anode & cathode compartment respectively, where following reactions take place -



The two electrodes are made of graphite admixed with Ni powder. The electrode conduct electrons into out of the cell. This facilitates the exchange of e^- b/w the gases & ions in solution. Hot aq^s KOH functions as electrolyte. It transport charges through the cell & the ions dissolved in it participate in the half reactions at each electrode.

It involve the combination of H_2 & O_2 at two electrodes. The cell voltage = $E^\circ(\text{Cathode}) - E^\circ(\text{Anode})$.

The standard emf of the cell -
 $E^\circ = 1.23 \text{ V}$ The experimental value is 1.15 V. The only product discharged by the cell is water. Usually a large number of these cells are stacked together in series to make a battery called fuel cell battery.

Uses → Hydrogen - oxygen fuel cell are used as auxiliary energy source in space vehicles, submarines, military vehicles etc.

The product water proved to be a valuable source of fresh water by the astronauts.

Advantages → 1) The fuel cell has high efficiency because it converts isothermally.

2) It is easy to maintain a fuel cell.

3) The chemical process is simple, as it is clean. It does not produce polluting exhaust.

4) Noise level of fuel cell is very low.

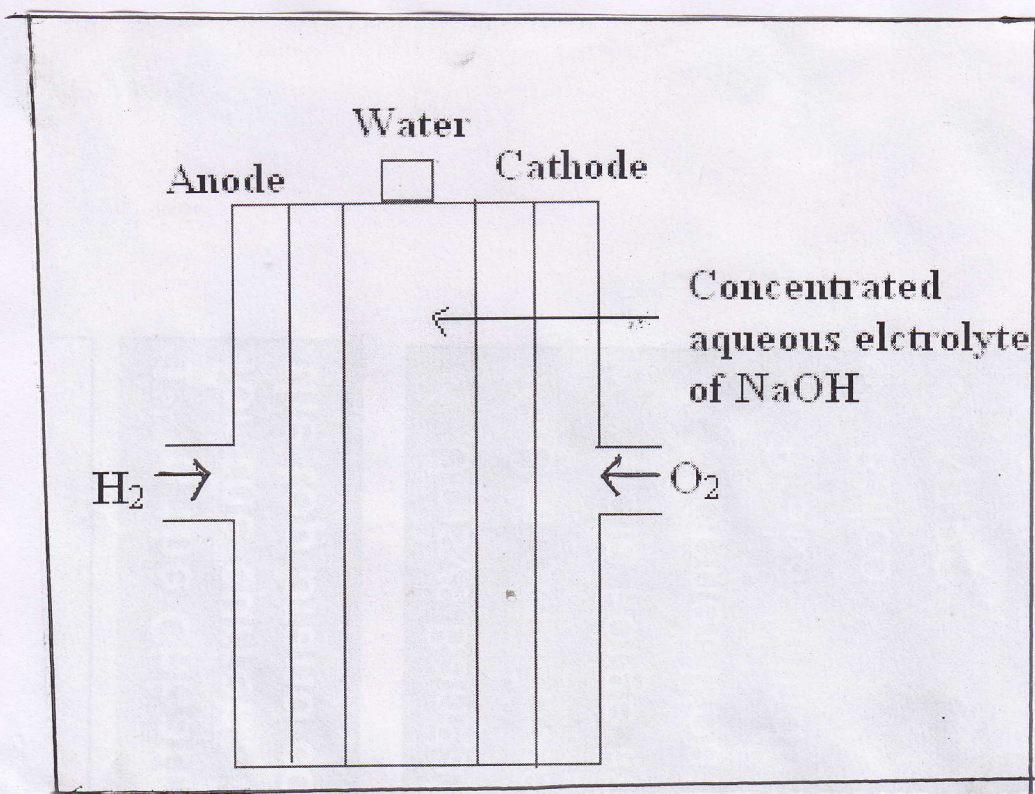


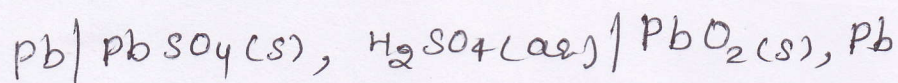
Fig- Fuel cell (Hydrogen-oxygen)

Lead storage cell (Lead Accumulator)

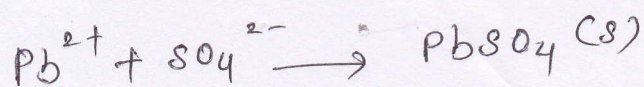
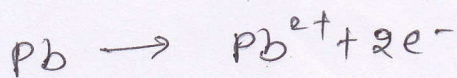
A storage cell is a secondary cell which can operate both as a voltaic cell & an electrical cell. When operating as a voltaic cell & an electrical cell, it supplies electrical energy & as such becomes run down. It must then be recharged, when being recharged, the cell operates as an electrolytic cell. Thus storage cell has the advantage of its ability to work both ways, to receive electrical energy & also supply it.

The common example of a storage cell is the lead acid cell. It essentially consists of two lead electrodes one of which is covered with an adherent layer of PbO_2 (positive electrode) on its surface.

The electrolyte is 20% of H_2SO_4 solution of specific gravity 1.15 at room temp. The cell is represented as,

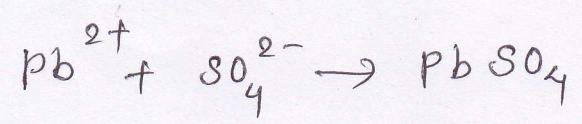
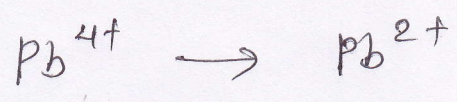
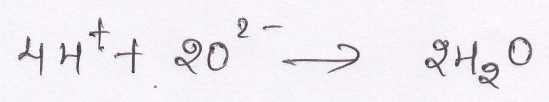
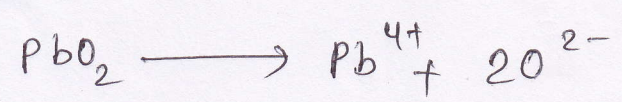


i) At the anode (negative electrode) lead dissolves to form Pb^{2+} ions, which react with sulphate ions to precipitate as sulphate.

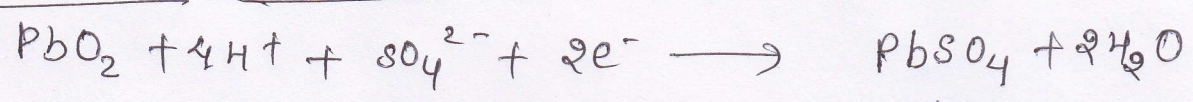


ii) At the cathode (positive electrode) the reactions

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Overall reaction \rightarrow



The plumbic ion is reduced to Pb^{2+} ions & ultimately lead sulphate is formed in the cathode as well.

Uses \rightarrow Accumulators are widely used in laboratory power stations, telephones, motors & cars, trains, electric clocks, radio sets, calling bells etc.

Disadvantages \rightarrow

- 1) Bigger in size.
- 2) It is not used in air crafts.

Solar cell :-

Working of solar
Solar cell is a device which converts solar energy into electrical energy or electricity. It is also called to be as photovoltaic cell.

Working & principle :-

Semiconductors are materials possessing very low electrical conductivity. For ex- silicon & germanium.

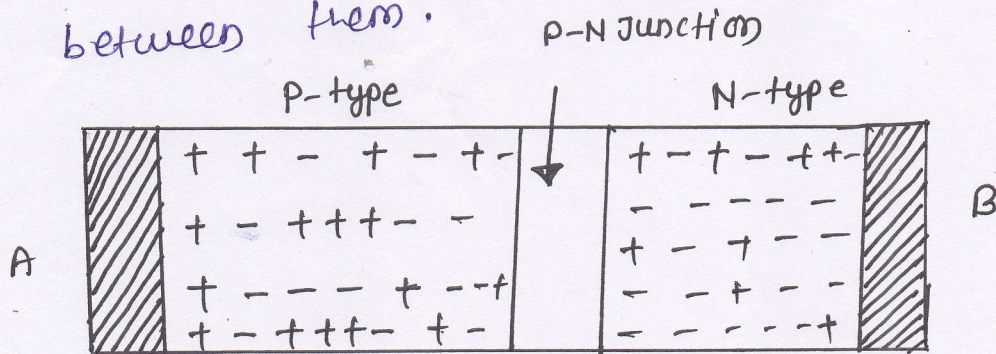
→ Thus semiconductors are neither conductors nor insulators (which does not allow the electricity to pass through it).

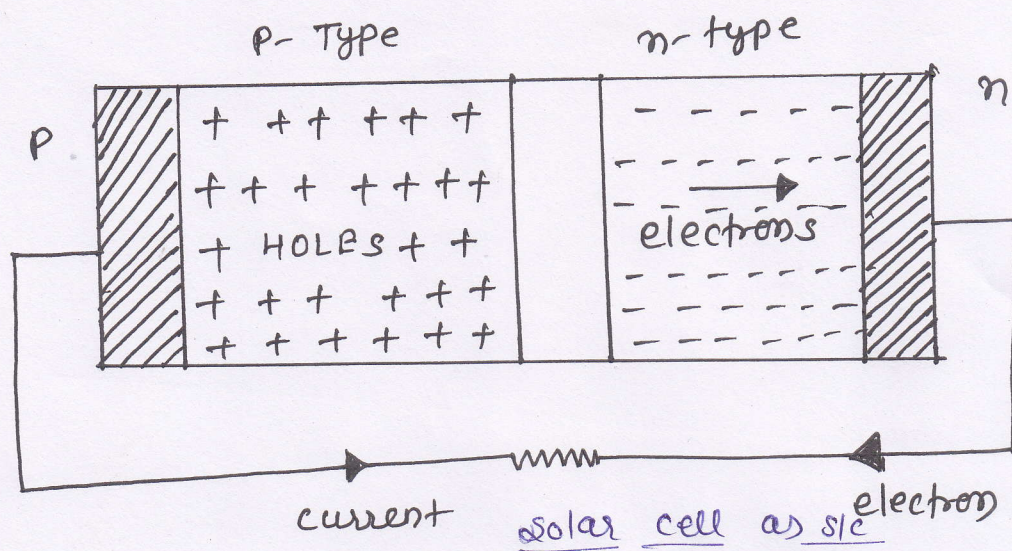
→ However it has been found that conductivity of an semiconductor can increase considerably when a certain impurities are added to them.

→ In solar cell when pentavalent impurity i.e. phosphorous is added, the semiconductor becomes excess in e^- (or N^- type) while when it is added with trivalent impurity i.e. arsenic it becomes excess in holes.

→ Moreover conductivity also increase when light falls on a semiconductor.

→ In a solar cell two types N type & P -type of semiconductor are used. pieces of semiconductor materials of two types are called wafers are so arranged that when light falls on them, then a potential difference (of about 0.4-0.5V) is produced between them.





Structure of solar cell :-

A typical solar cell consist of two very thin layers of materials. The lower layer has atoms with single electrons in the outer orbital, which are easily lost.

The upper layer has atoms lacking one electrons from their outer orbital & hence can readily gain electron.

Application :- For producing electricity an artificial satellites, space probes etc.

- ② For providing electricity for street lighting, water pump operation & running radio & T.V sets, in remote area.
- ③ For operating electronic / quartz watches, calculators etc.
- ④ To provide electronic power to light houses.