

Chemistry Unit-3

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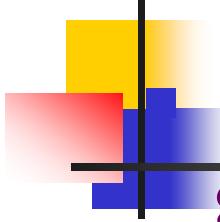
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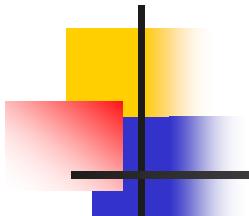
Raigarh C.G.

Unit-3 Syllabus



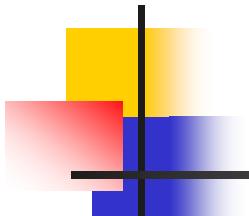
Types of Corrosion (**dry, wet, atmospheric, galvanic and Concentration corrosion**)

- Theories of corrosion; Protective measure against corrosion.
- Factors effecting corrosion;
- **Pitting Corrosion; Water line corrosion; Underground corrosion; Stress corrosion; Micro biological corrosion** Corrosion fatigue.



Unit-3

- Batteries and Battery Technology
 - Primary Cells;
 - Secondary batteries;
 - Reserve Batteries;
 - fuel cells; Solar cells



L-21 Introduction CORROSION

Any process of deterioration

- **consequent loss of**
- **a solid metallic material**

**through an unwanted chemical or
electrochemical attack**

- **by its environment ,**
- **started at its surface**

is called corrosion.

a process "reverse of extraction of metals".

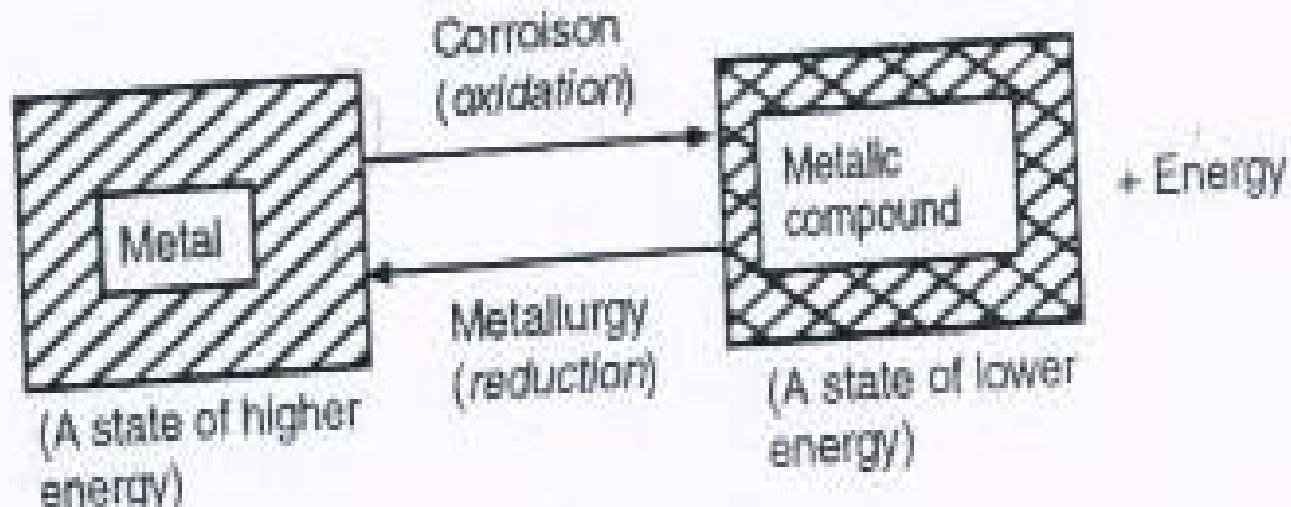
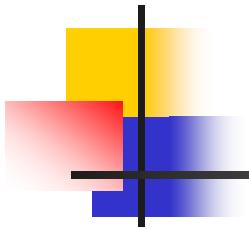
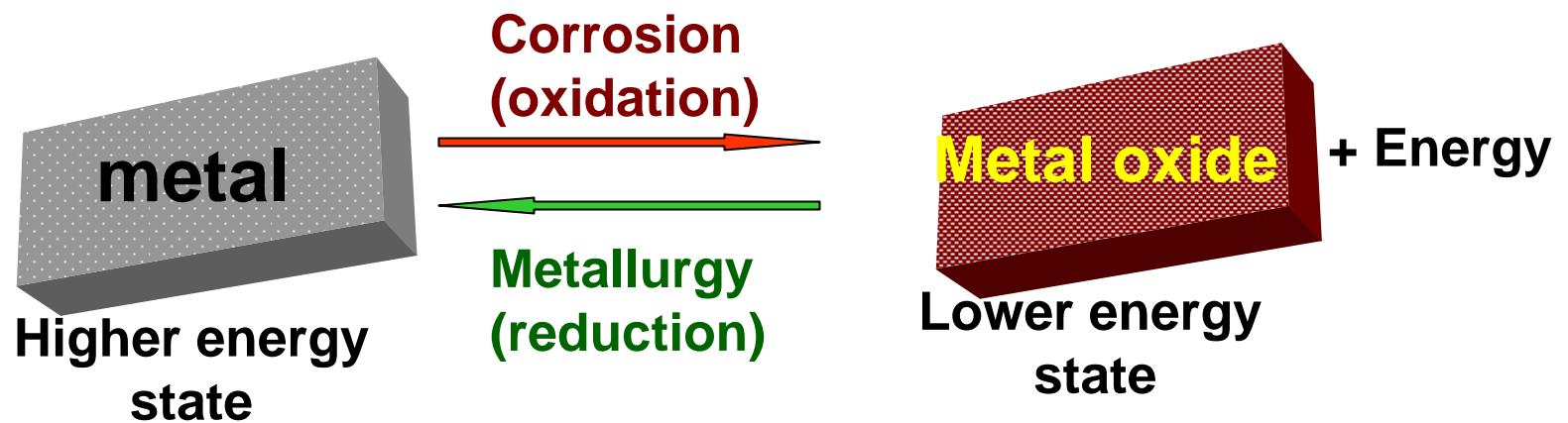
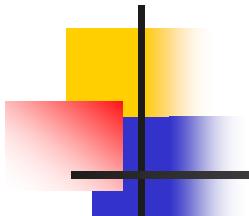


Fig. 1. Corrosion and oxidation processes.



CORROSION





L-21 Introduction CORROSION

Example

Rusting of IRON

Fe_3O_4 , reddish scale

Green film on surface of Cu

$[\text{CuCO}_3 + \text{Cu}(\text{OH})_2]$,

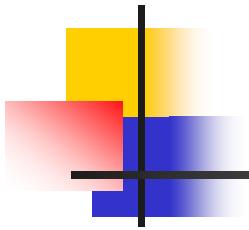
Basic copper carbonate

L-21 Introduction

Gravity of corrosion problem

- Approximate estimated loss of metal ,as
- 2 to 2.5 billion dollars/annum all over the world.
- In INDIA Rs. 200 crores /annum.

- Enormous waste/destruction of machines, equipments and different type of metallic products /eqipments / bridge etc.

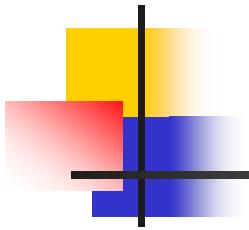


L-21 Introduction CORROSION

Dry/Chemical Corrosion

Direct chemical action of environmental gases such as O_2 , H_2 , halogen , H_2S , SO_2 , N_2 or any anhydrous liquid

with metal surface in immediate proximity

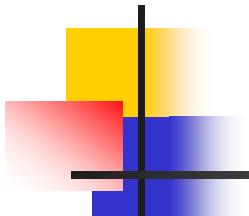


L-21 Introduction CORROSION

Dry/Chemical Corrosion

Three main types:

1. **Oxidation corrosion**
2. **Corrosion by other gases**
3. **Liquid metal corrosion**



L-21 Introduction CORROSION

Oxidation corrosion

Alkali metals

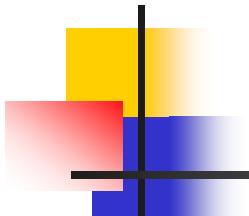
(Li, Na, K Rb etc.)

and alkaline earth metals

(Be, Mg, Ca, Sr etc.) are

rapidly oxidize at low temperature. At high temperature almost all metals are oxidized.

[Except Ag, Au, & Pt]



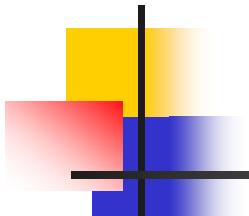
L-21 Introduction CORROSION

Oxidation corrosion

On Anode:



(Loss of electrons, oxidation process)



L-21 Introduction

Oxidation corrosion

On Cathode:



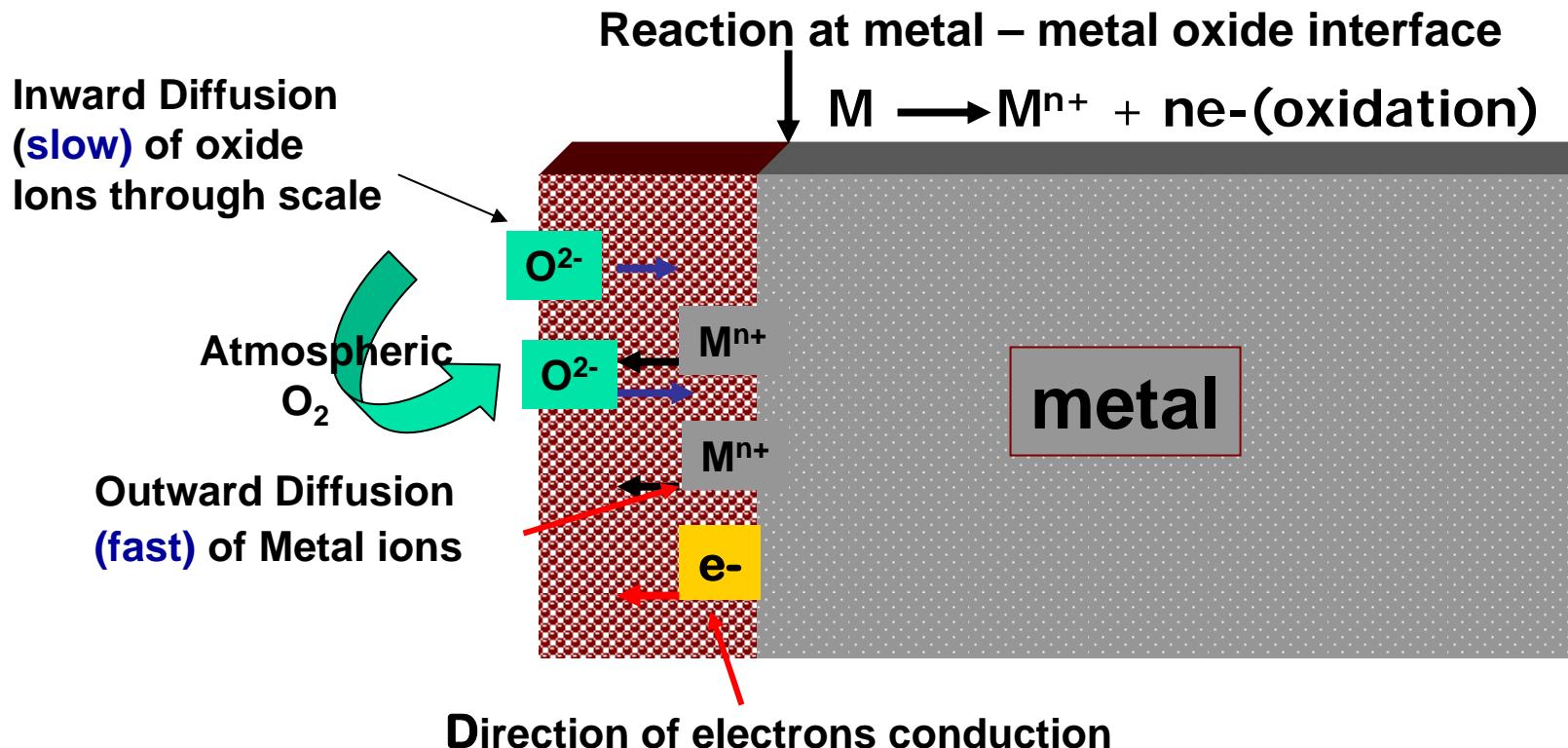
(Gain of electron ,reduction process)

L-21 Introduction

Oxidation corrosion

Oxidation corrosion

Oxidation mechanism of metals



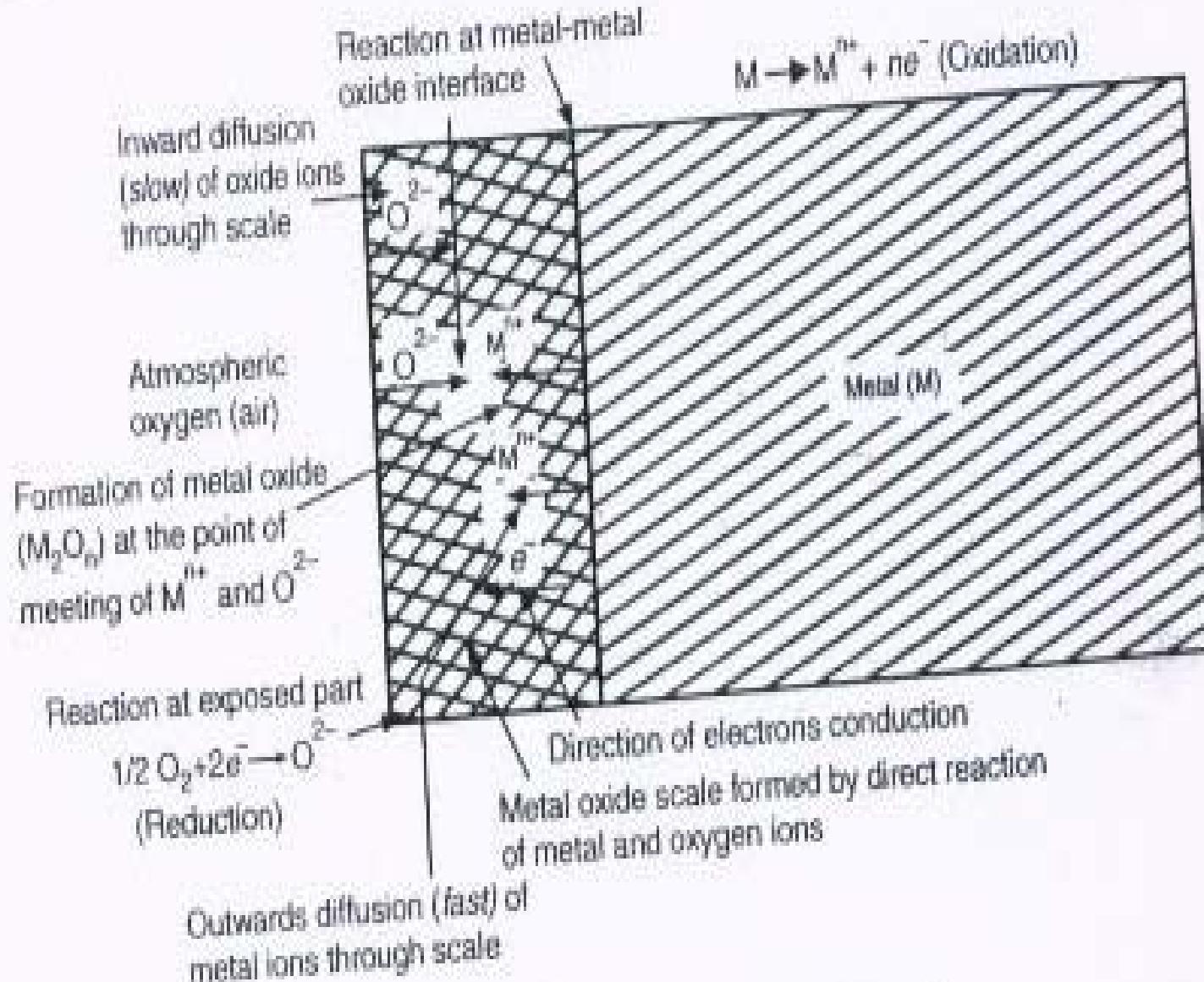
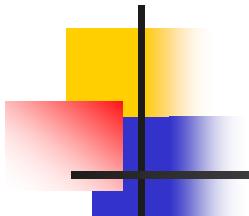


Fig. 2. Oxidation mechanism of metals.



Oxidation corrosion

Chemical reactions:

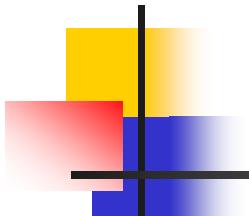


(loss of electrons on anode)



(gain of electrons on cathode)



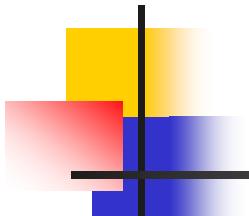


L-21 Introduction

Oxidation corrosion

Nature of the oxides formed

- 1. Stable**
- 2. Unstable**
- 3. Volatile**
- 4. porous**



L-21 Introduction

Oxidation corrosion

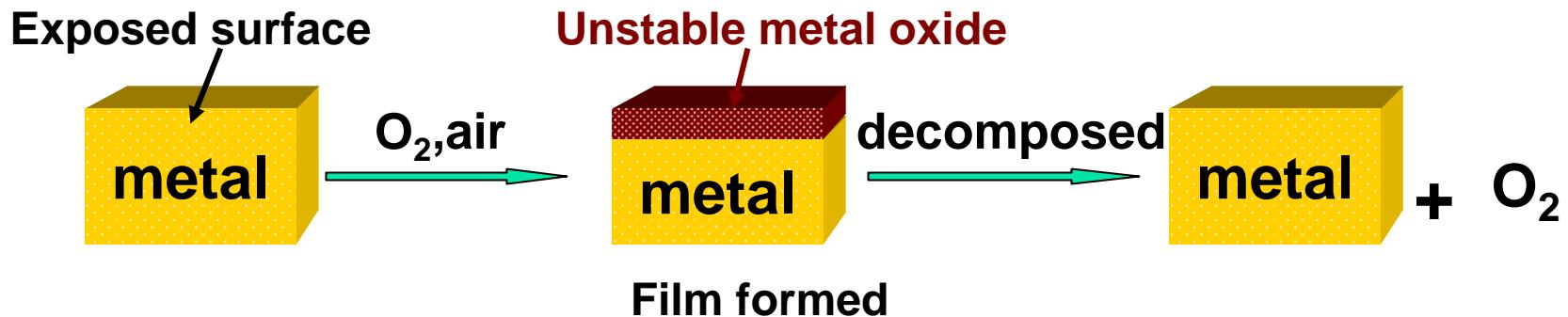
1 .Stable

- The oxide film on the surface of
 - Al , Pb , Sn , Pt, etc.
 - Stable, Tightly adhering and
 - impervious in nature.
- Prevent further corrosion

L-21 Introduction

Oxidation corrosion

2. Unstable

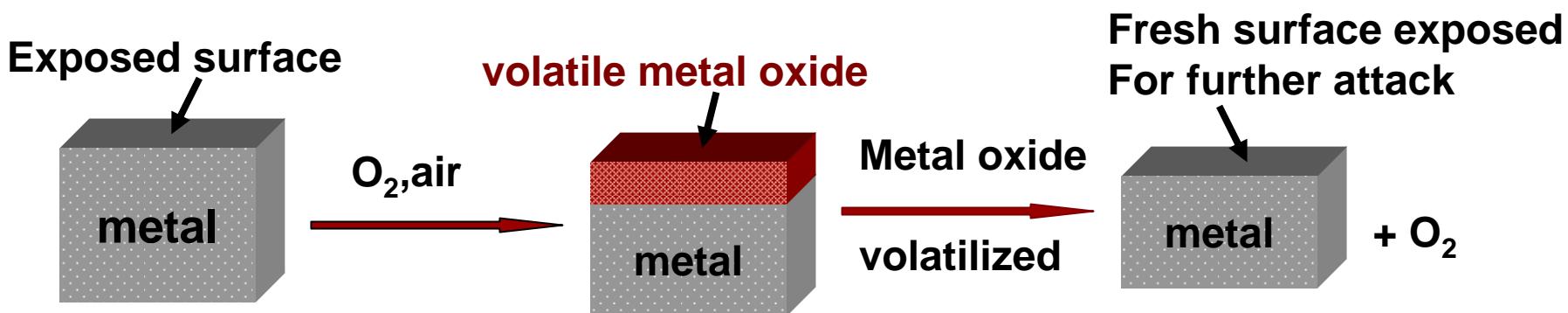


Oxidation corrosion is not possible
Example: Silver, Gold & Platinum

L-21 Introduction

Oxidation corrosion

■ 3. Volatile

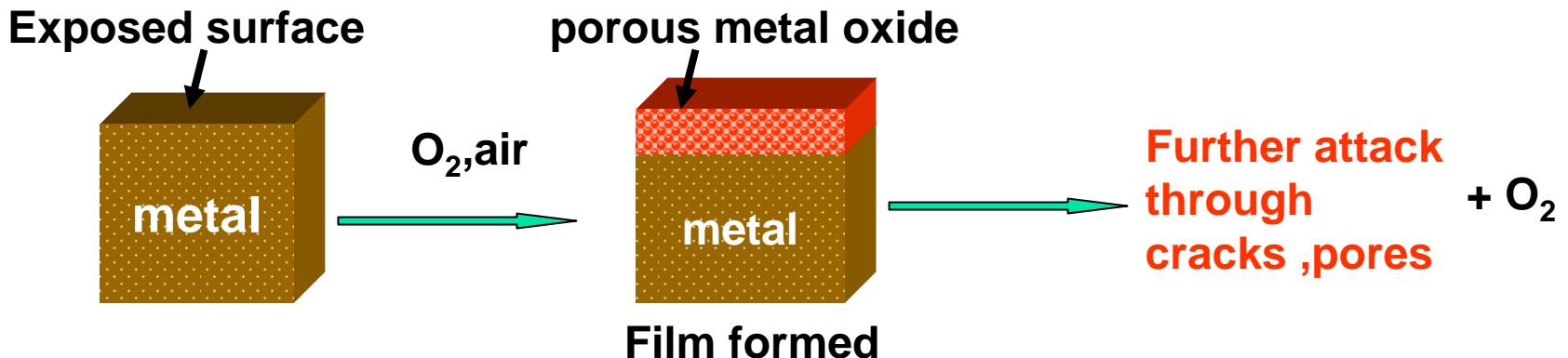


Example: Molybdenum Oxide
MoO₃ is volatile

L-21 Introduction

Oxidation corrosion

■ 4. Porous



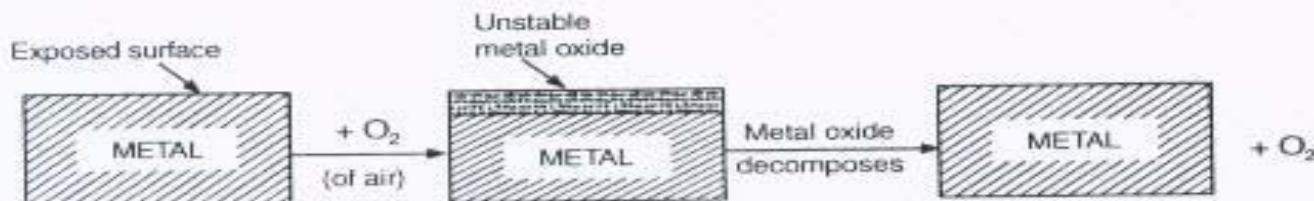


Fig. 3. Unstable oxide layer.

(iii) **Volatile**, i.e., the oxide layer *volatilizes* as soon as it is formed, thereby leaving the underlying metal surface *exposed* for further attack. *This causes rapid and continuous corrosion*, leading to excessive corrosion, e.g., molybdenum oxide (MoO₃) is volatile.

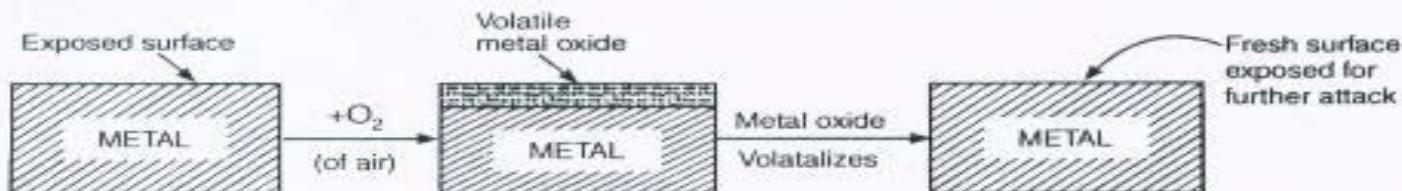


Fig. 4. Volatile oxide layer.

(iv) **Porous**, i.e., having pores or cracks. In such a case, the atmospheric oxygen have *access* to the underlying surface of metal, through the pores or cracks of the layer, thereby the *corrosion continues unobstructed*, till the entire metal is completely converted into its oxide.

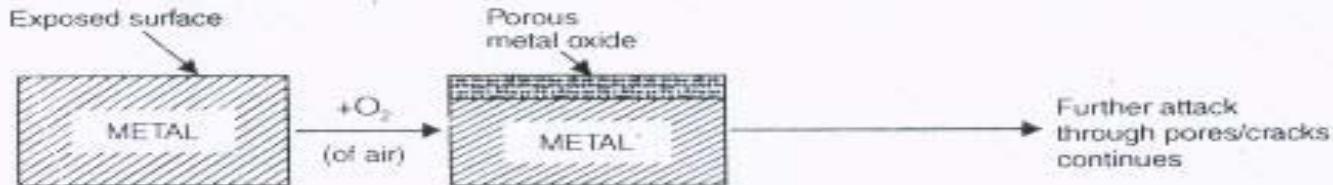


Fig. 5. Porous oxide layer.

* A layer is called *film*, when its thickness is less than about 300 Å (1 Å = 10⁻⁸ cm) ; and it is called *scale*, when its thickness exceeds this value.

L-21 Introduction

Oxidation corrosion

Pilling-bedworth rule:

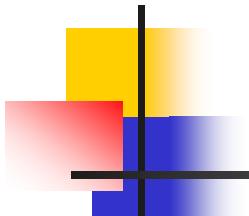
“An oxide is protective or non-porous,if the volume of the oxide is at least as great as the volume of the metal from which it is formed”.

Or

If the volume of the oxide is less than the volume of the metal the layer is porous..it cannot prevent the access of O_2 to the fresh metal surface..

L-21 Introduction

Oxidation corrosion



Pilling-bedworth rule:

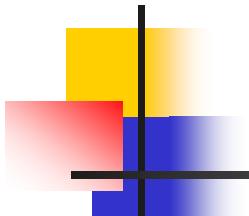
Or

If the volume of the oxide is less than the volume of the metal the layer is porous..

e.g. Aluminium forms oxide whose volume is greater than Al. Non-porous protective layer is formed. But

L-21 Introduction

Oxidation corrosion



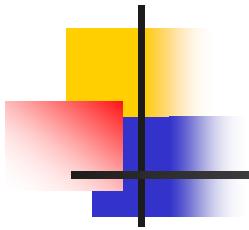
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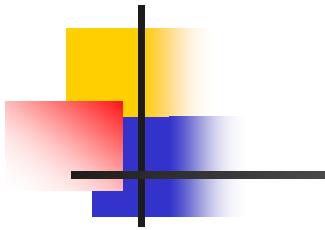
Alkali and alkaline earth metal oxide's volume is less than the metal itself. Develop cracks and pores.



L-22 Wet corrosion

This occurs when

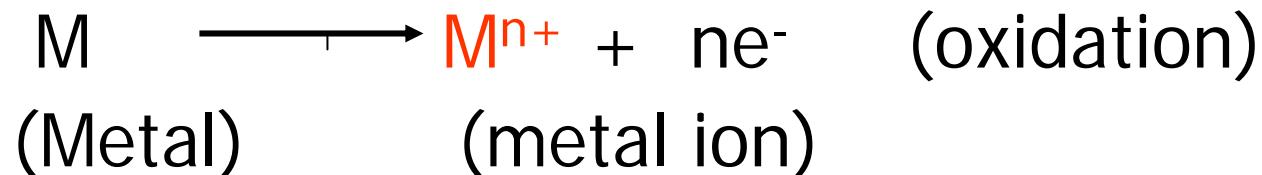
1. A Conducting liquid is in contact with metal
or
2. Two Dissimilar metal or Alloys are
 - Immersed ,
 - Dipped partially
 - In a solution



L-22 Wet corrosion

Corrosion always occurs at anodic areas

At Anode



M^{n+} \longrightarrow dissolves in solution



Forms compound such as oxide

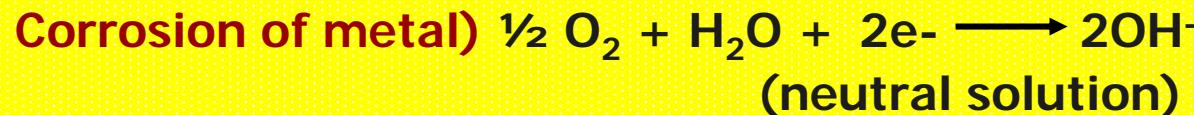
L-22 Mechanism of wet or electrochemical corrosion

■ At anodic area: $M \longrightarrow M^{n+} + ne^-$

Anodic area



(dissolution or

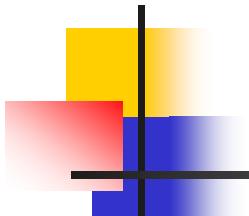


Electron flow



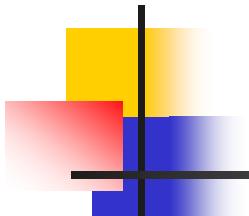
Cathodic area

■ At cathode: i) Evolution of H_2 or
ii) Absorption of O_2 takes place



L-22 Mechanism of wet or electrochemical corrosion

- At anodic area: $M \longrightarrow M^{n+} + ne^-$
- Cathodic reaction:
 - 1) Evolution of hydrogen (acidic)
 - 2) Absorption of oxygen (neutral)



L-22 Mechanism of wet or electrochemical corrosion

Evolution of hydrogen

In acidic environment

Example: industrial wastes and solutions of
non -oxidizing acids



- Electrons flow through metal from anode to cathode

L-22 Mechanism of wet or electrochemical corrosion

At Anode:



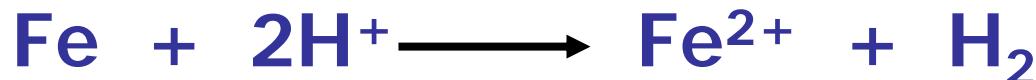
(oxidation ,loss of electrons)

At Cathode



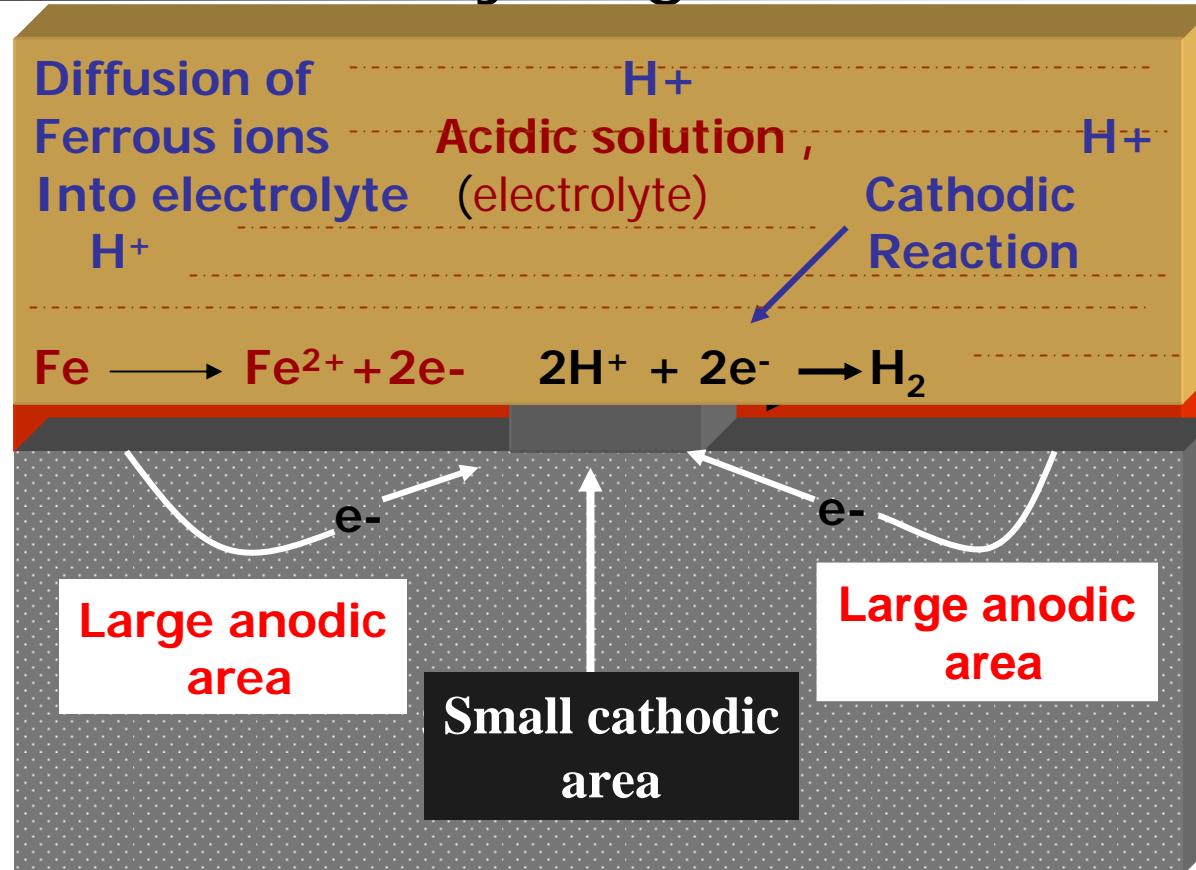
(reduction, gain of electron)

Over all reaction



L-22 Mechanism of wet or electrochemical corrosion

■ Evolution of hydrogen



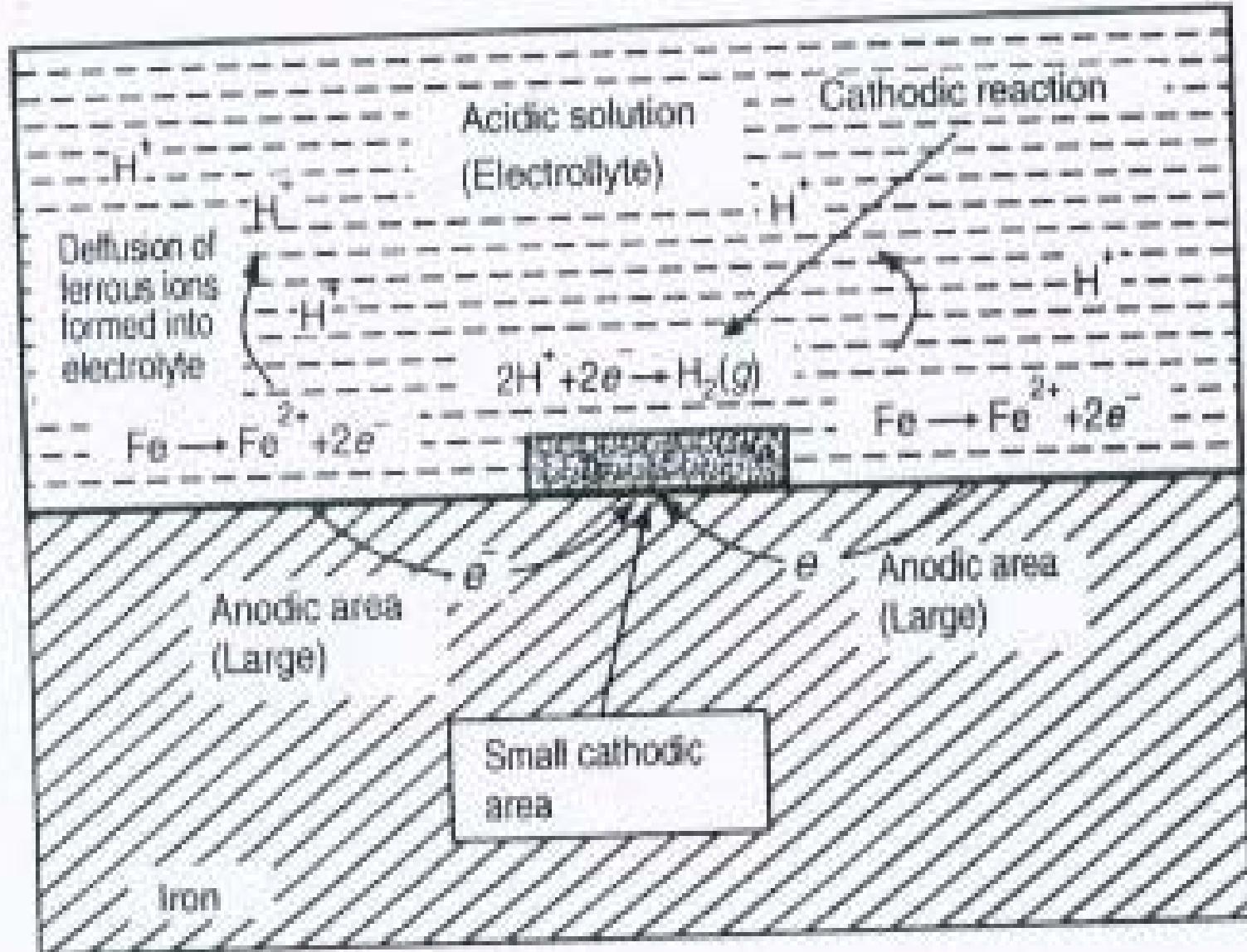
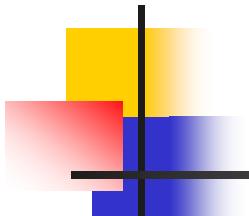


Fig. 6. Mechanism of wet corrosion by hydrogen evolution.

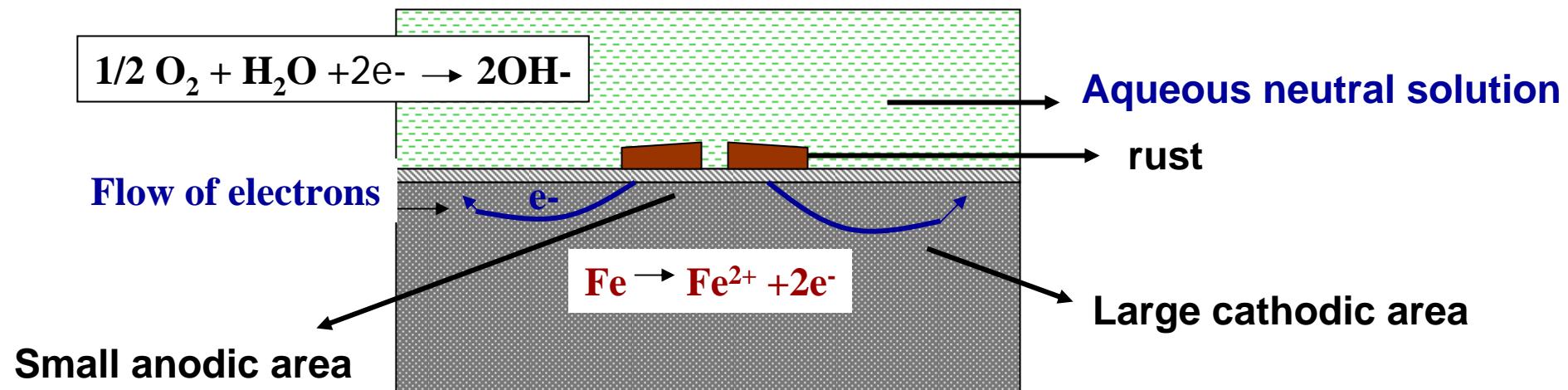


L-22 Mechanism of wet or electrochemical corrosion

- **Absorption of oxygen**
- *In neutral environment*
- Rusting of iron , in presence of NaCl solution
- Fe in presence of **Oxygen** forms iron oxide
- **Anodic area** created on surface (**smaller**)
- Metal part act as cathode (**large**)

L-22 Mechanism of wet or electrochemical corrosion

- Absorption of oxygen



example of this type of corrosion. The surface of iron is, usually, coated with a thin film of iron oxide. However, if this iron oxide film develops some cracks, anodic areas are created on the surface ; while the well-metal parts act as cathodes. It follows that *the anodic areas are small surface parts ; while nearly the rest of the surface of the metal forms large cathodes*,

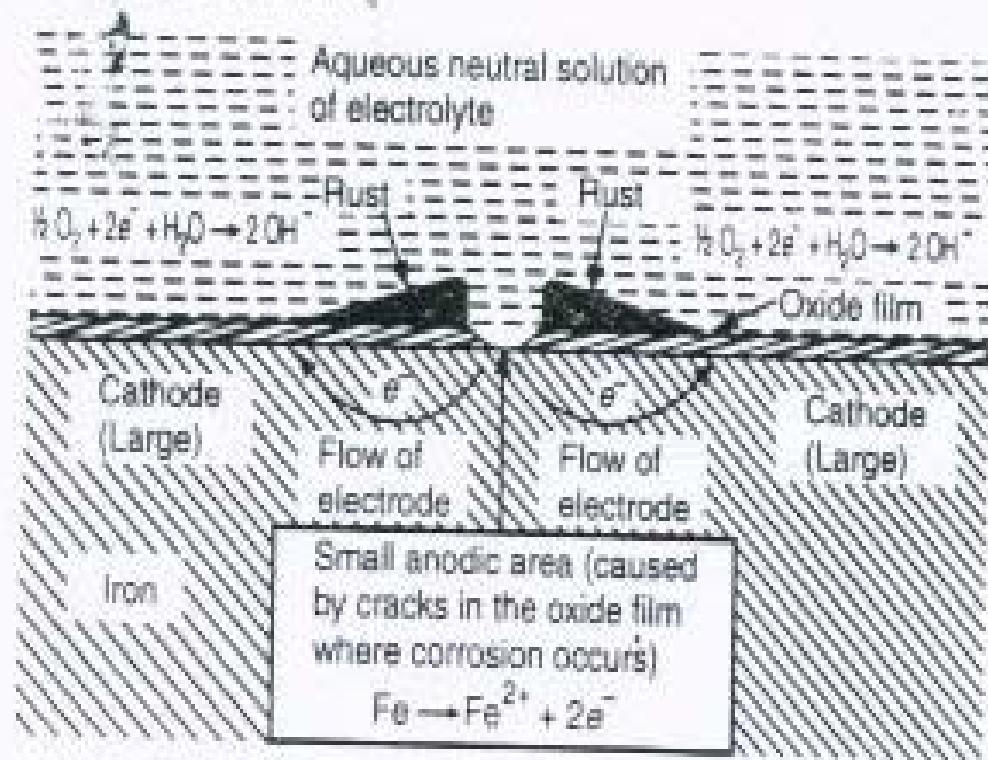


Fig. 7. Mechanism of wet corrosion by oxygen absorption.

At the anodic areas of the metal (iron) dissolves as ferrous ions with liberation of electrons.

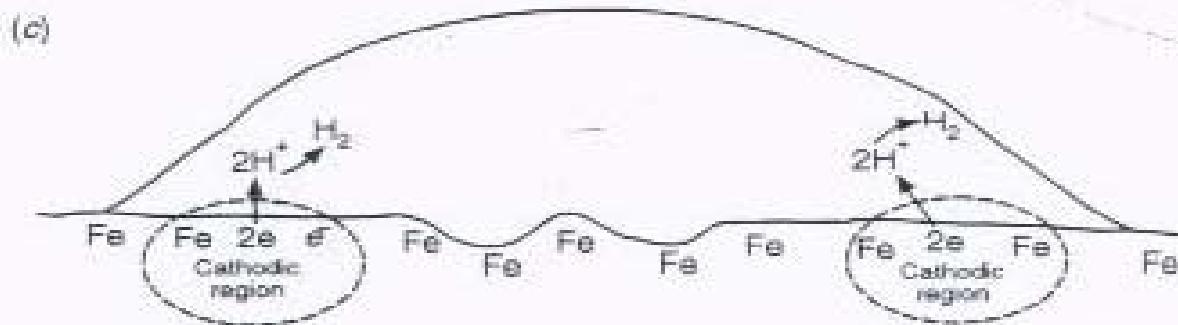
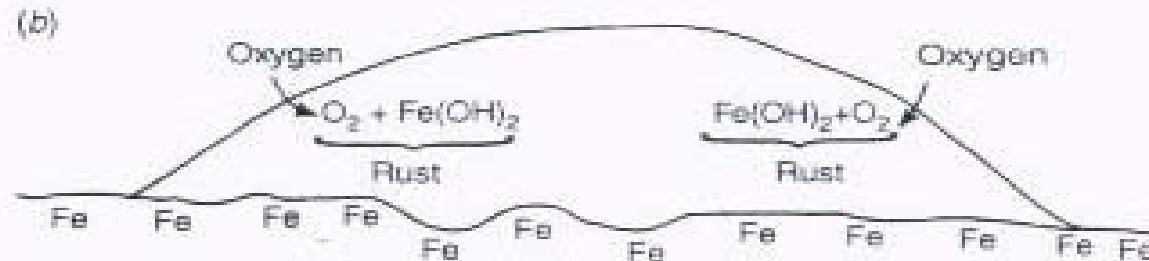
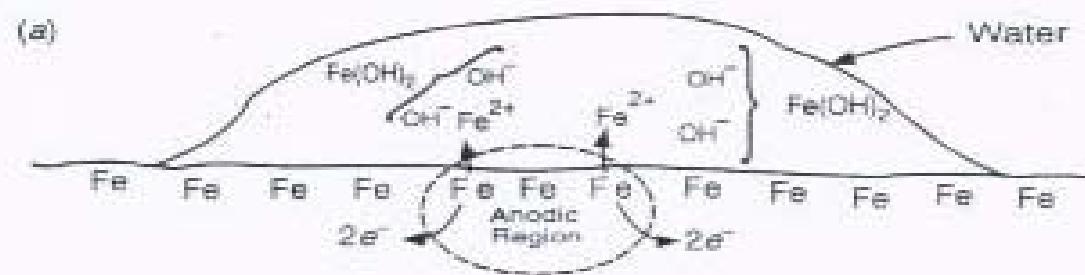
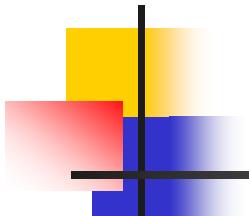


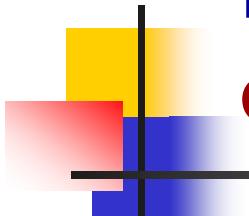
Fig. 8. Three stages in the rusting of iron. (a) Fe^{2+} ions go into the water and make Fe(OH)_2 with OH^- ions present in the water. Each Fe^{2+} ion leaves $2 e^-$ in the metal lattice. (b) At the surface of the drop there is more oxygen dissolved. Here rust is made. Where Fe atoms have made Fe^{2+} , holes appear in the lattice. (c) The electrons released combine with H^+ ions in water to give H_2 gas.



L-22 Mechanism of wet or electrochemical corrosion

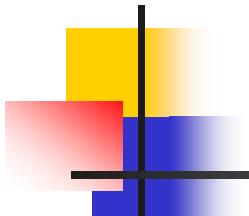
- Anodic reaction
- $\text{Fe} \longrightarrow \text{Fe}^{2+} + 2\text{e}^-$
- (oxidation, loss of electron)

- Cathodic reaction:
- $2\text{e}^- + 1/2 \text{O}_2 + \text{H}_2\text{O} \longrightarrow 2\text{OH}^-$



L-22 Mechanism of wet or electrochemical corrosion

- Fe^{2+} ions (at anode) and OH^- ions (at cathode) diffuse
- Ferrous hydroxide is precipitated .
- $\text{Fe}^{2+} + 2\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_2 \downarrow$



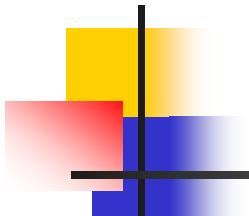
L-22 Mechanism of wet or electrochemical corrosion

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

.



yellow rust , ($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$)

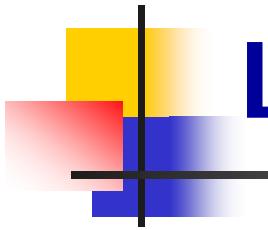


L-22 Mechanism of wet or electrochemical corrosion

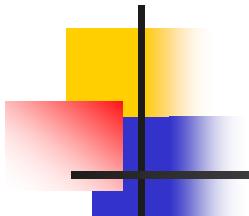
(ii) If the supply of oxygen is limited,

the corrosion product may be even

black anhydrous magnetite, Fe_3O_4 .



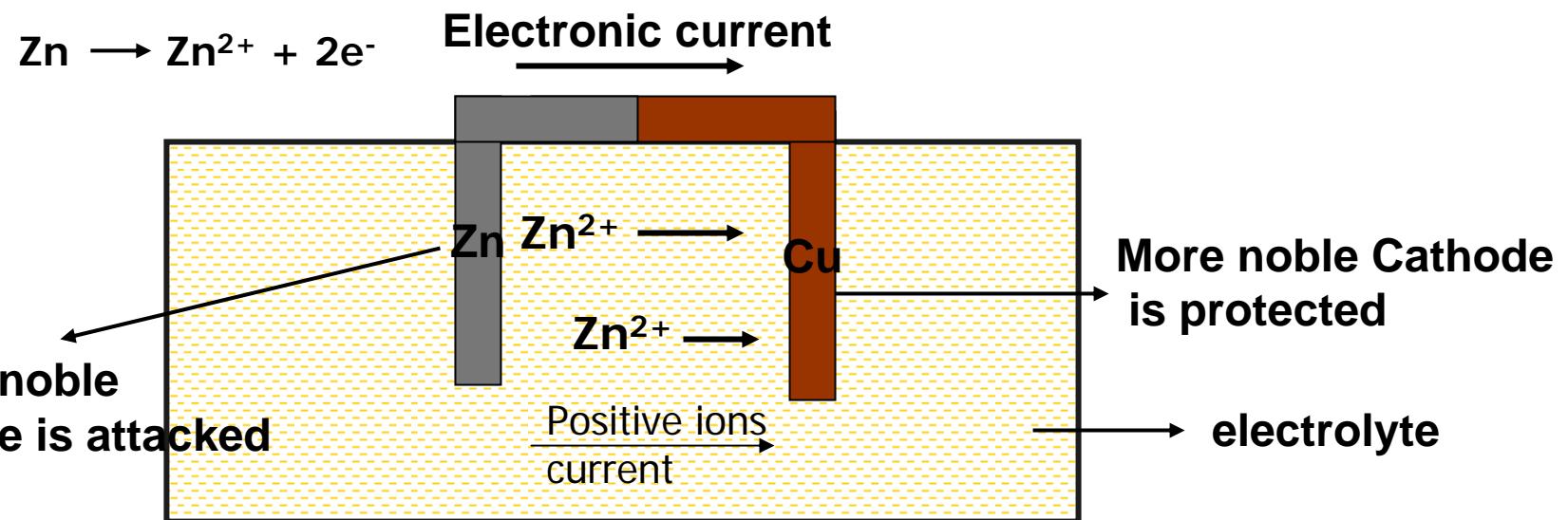
L-22



L-23 GALVANIC OR BIMETALLIC CORROSION

- When two dissimilar metals
- **(e.g., zinc and copper)**
- electrically connected and exposed to an electrolyte,
- **the metal higher in electrochemical series undergoes corrosion.**

L-23 Galvanic or Bimetallic Corrosion



GALVANIC (OR BIMETALLIC) CORROSION

When two **dissimilar metals** (e.g., zinc and copper) are electrically connected and exposed to an electrolyte, the metal **higher in electrochemical series undergoes corrosion**. This type of corrosion, is called "galvanic corrosion". In the above example, zinc (higher in electrochemical series) forms the anode and is attacked and gets dissolved ; whereas copper (lower in electrochemical series or more noble) acts as cathode.

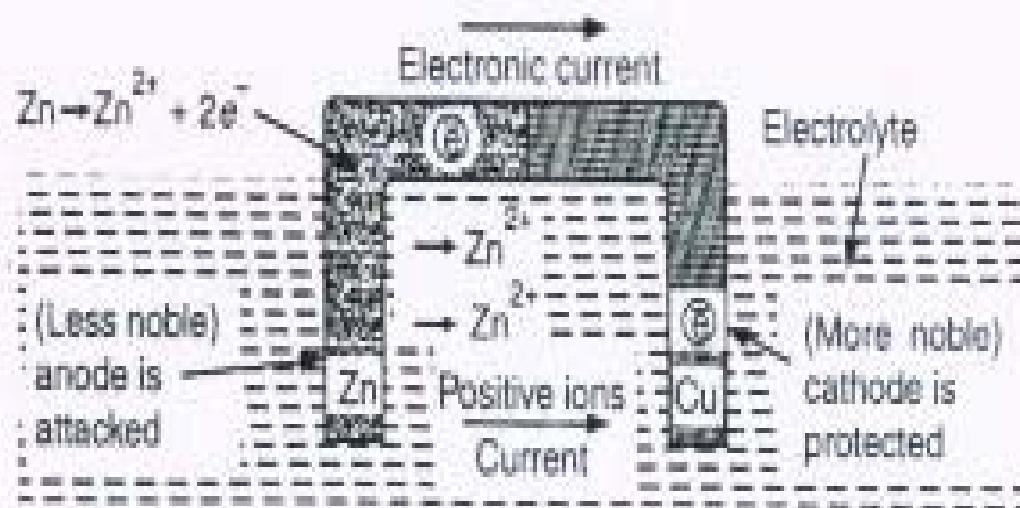
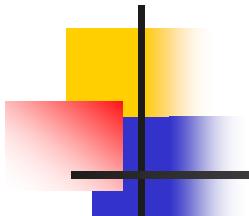


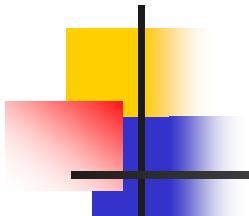
Fig. 9. Galvanic corrosion.



L-23 Mechanism

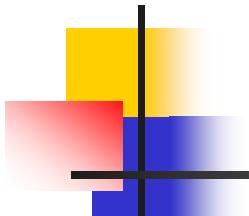
- In acidic solution, the corrosion occurs by the **hydrogen evolution process**;
- while in **neutral or slightly alkaline solution, oxygen absorption occurs**.
- The electron-current flow from the anodic metal zinc,





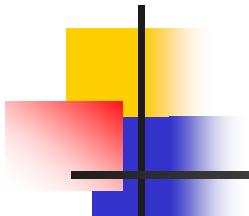
L-23 Mechanism

- zinc (higher in electrochemical series) forms the anode and is attacked and gets dissolved;
- whereas copper (lower in electrochemical series or more noble) acts as cathode.



L-23 Examples

- (i) Steel screws in a brass marine hardware;
- (ii) Lead - antimony solder around copper wire;
- (iii) A steel propeller shaft in bronze bearing;
- (iv) Steel pipe connected to copper plumbing.

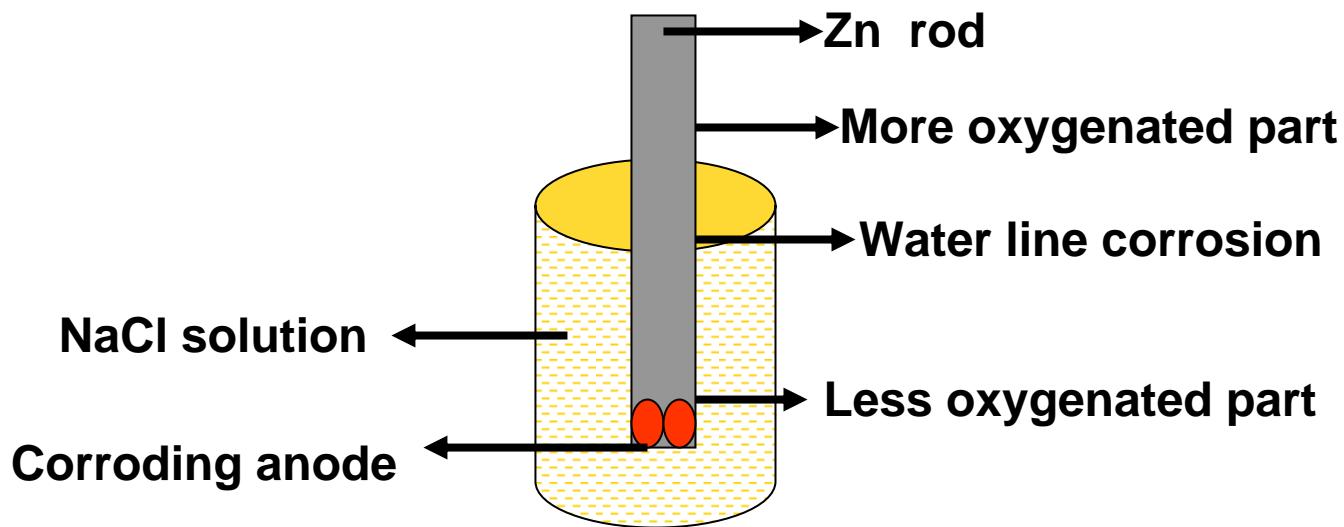


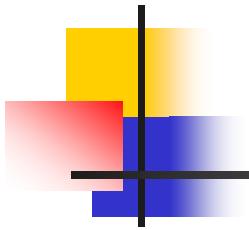
L-23 CONCENTRATION CELL CORROSION

corrosion is due to electrochemical attack on the metal surface,

- exposed to an electrolyte of
- **varying concentrations or**
- **of varying aeration.**

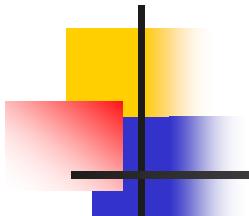
L-23 Concentration cell corrosion





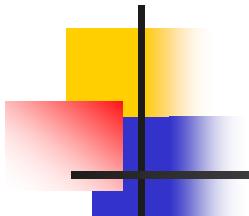
L-23 Concentration cell corrosion

- This may be the result of local difference in metal - ion concentrations,
- caused by local temperature differences or inadequate agitation or slow diffusion of metal-ions, produced by corrosion.



L-23 Concentration cell corrosion

- It has been found experimentally that “poor-oxygenated parts are anodic”
- Consequently, a **differential aeration** of metal causes a flow of current,
- called the **differential current**.



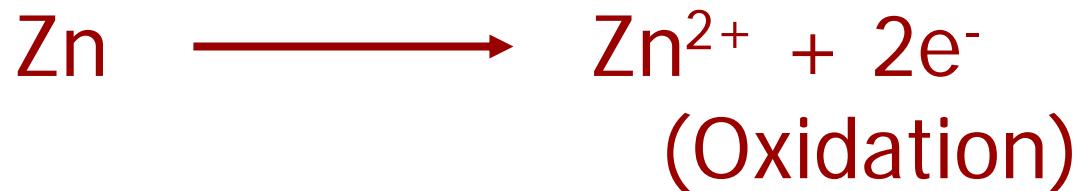
L-23 Concentration cell corrosion

- Zinc will dissolve at the anodic areas,
- and oxygen will take up electrons
- at the cathodic areas to form
- **hydroxyl ions.**

L-23 Concentration cell corrosion

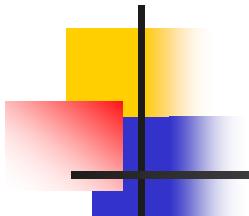
Chemical reaction

Anodic reaction:



Cathodic reaction:

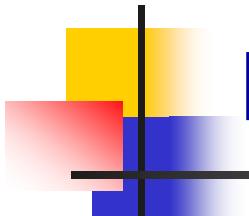




L-23 Concentration cell corrosion

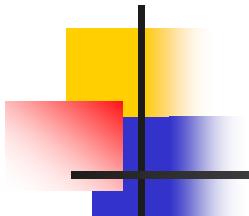
Chemical reactions

- The circuit is completed by migration of ions,
- through the electrolyte,
- and flow of electrons,
- through the metal, from anode to cathode.



L-23 Concentration cell corrosion

- Corrosion is accelerated under accumulation of dirt sand,
- scale or other, contamination
- The result is localized corrosion,
- due to non - uniform corrosion.

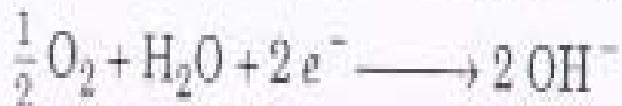


L-23 Concentration cell corrosion

- Metals exposed to aqueous media corrode under blocks of wood or pieces of glass,
- which screen that portion of metal from oxygen access.
-



(Oxidation)



(Reduction)

The circuit is completed by migration of ions, through the electrolyte, and flow of electrons, through the metal, from *anode to cathode*.

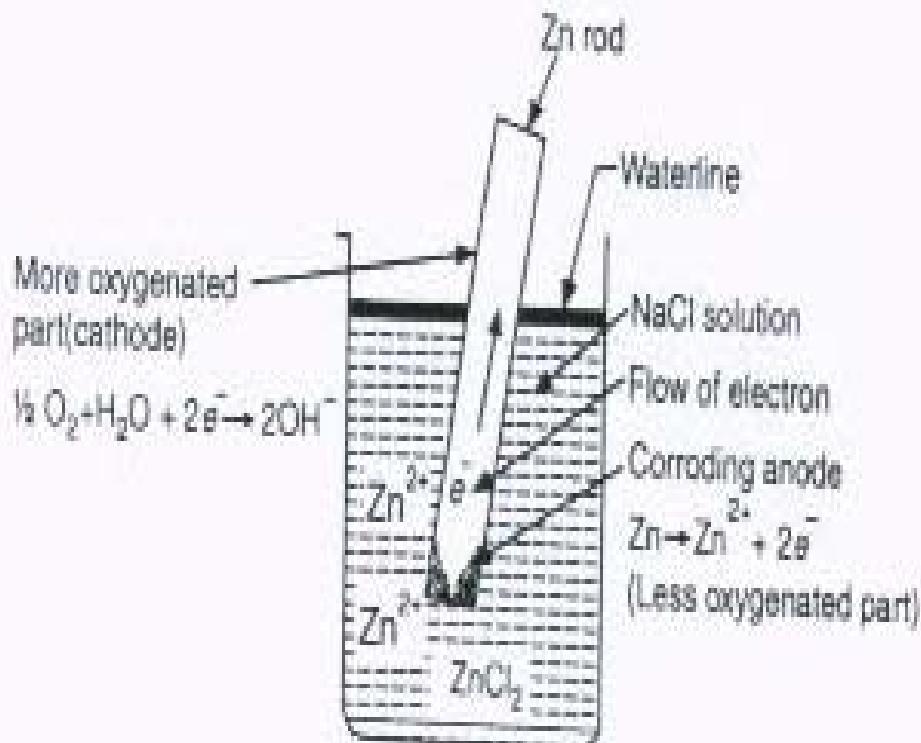
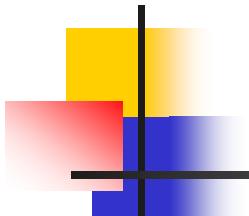


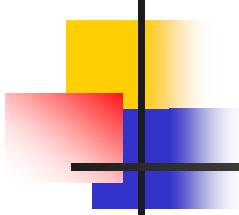
Fig. 10. Mechanism of differential aeration attack caused by partial immersion of a metal.



L-24 UNDERGROUND OR SOIL corrosion

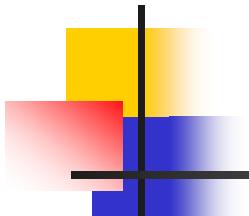
The corrosiveness of a soil depends upon :

- (i) its acidity,**
- (ii) degree of aeration,**
- (iii) electrical conductivity,**



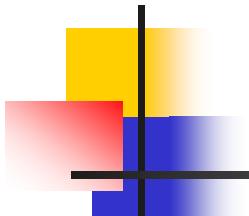
L-24 UNDERGROUND OR SOIL CORROSION

- (iv) its moisture and salts content,
- (v) presence of bacteria and micro-organisms, and
- (vi) soil texture.



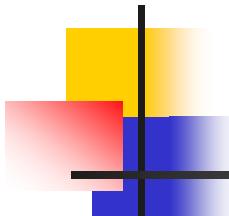
L-24 UNDERGROUND OR SOIL CORROSION

- Gravelly or sandy soils are very porous and strongly- aerated.
- If a metal pipe is buried in such a soil, corrosive conditions are similar to those under wet condition,
- and the corrosion rate will be governed by amount of moisture content in the soil.



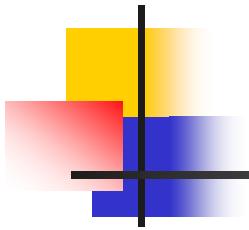
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- Pitting corrosion is a localized accelerated attack, resulting in the
- formation of cavities around which the metal is relatively unattached.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- pitting is, usually, the result of the breakdown or cracking of the protective film on a metal at specific points making...
- pinholes, pits and cavities in the metal.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

Breakdown of the protective film caused by :

- (i) surface roughness or non-uniform finish,
- (ii) scratches or cut edge,
- (iii) local straining of metal, due to **non-uniform stresses**,

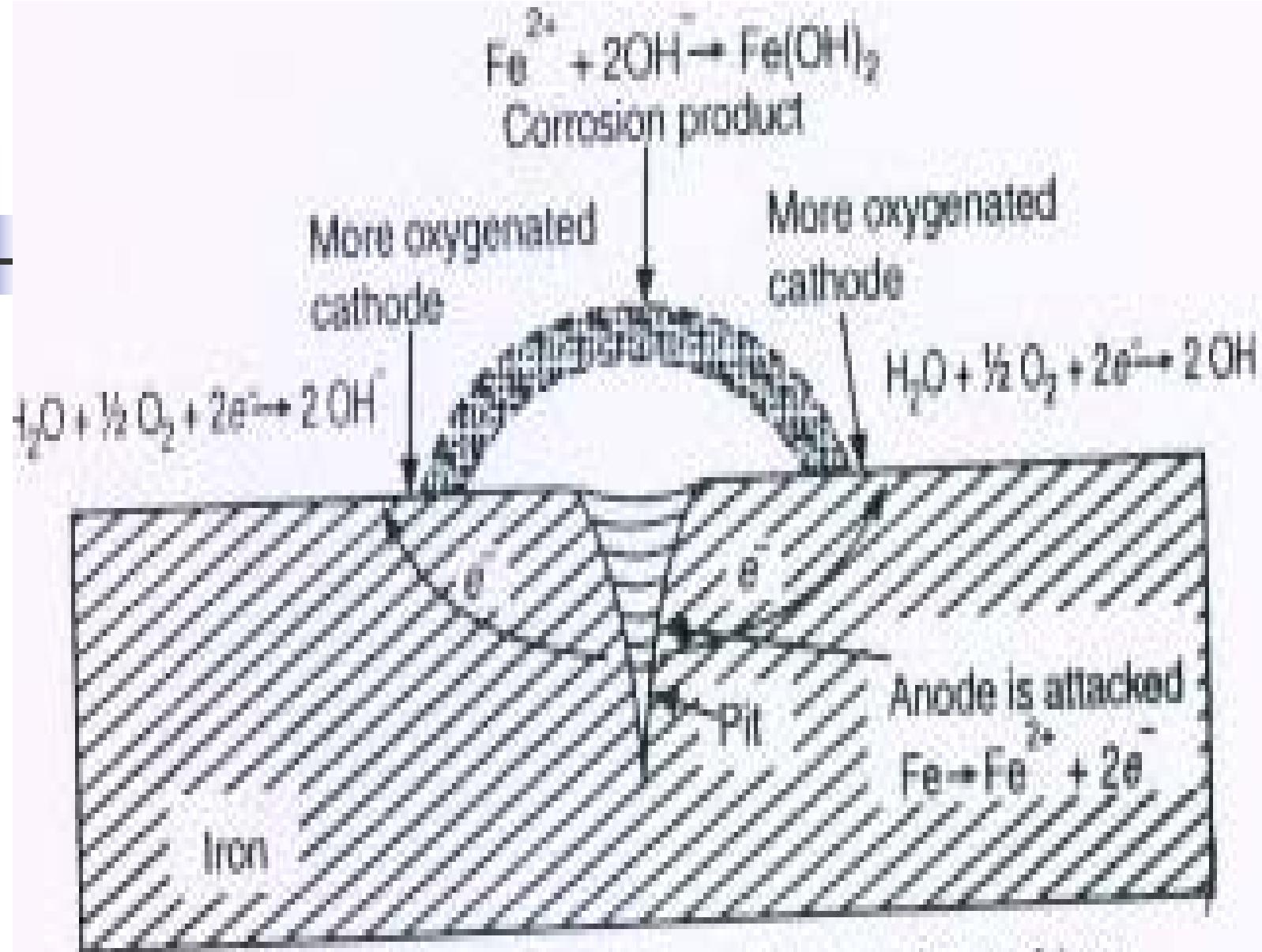
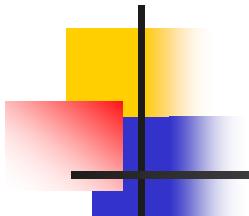


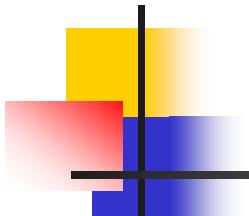
Fig. 14. Pitting corrosion at the surface of iron.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

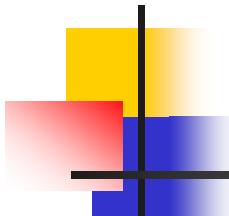
- (iv) alternating stresses,
- (v) sliding under load,

- (vi) impingement attack (caused by the turbulent flow of a solution over a metal surface),
- (vii) chemical attack.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

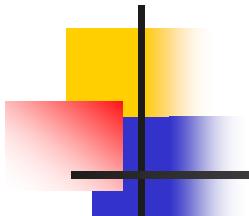
1. Differential amount of oxygen in contact with the metal the **small part** (underneath the impurity) become the anodic areas
- 2 . Surrounding large parts become the cathodic areas.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- Intense corrosion, therefore,
- start just underneath the impurity.

- Once a small pit is formed,
- the rate of corrosion will be increased.

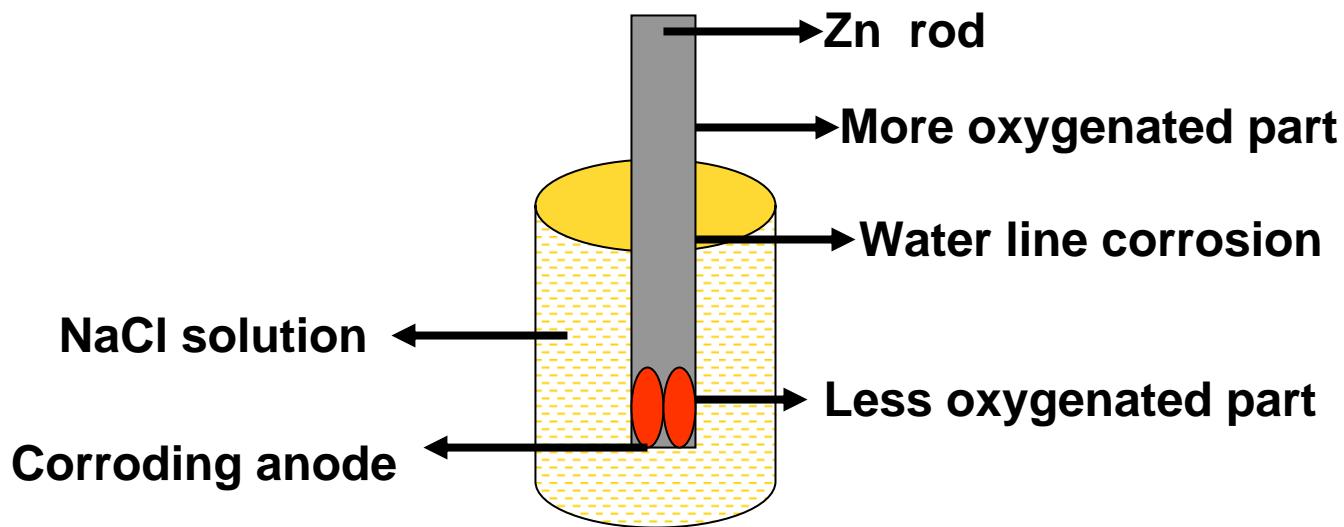


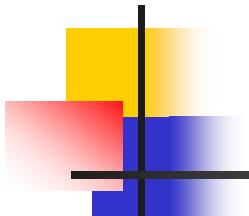
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

WATERLINE CORROSION

- When water is stored in a steel tank, it is generally found that
- the **maximum amount of corrosion** takes place along
- a **line just beneath** the level of the **water meniscus**.

L-23 Concentration cell corrosion



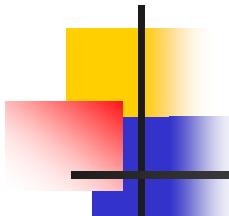


L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

WATERLINE CORROSION

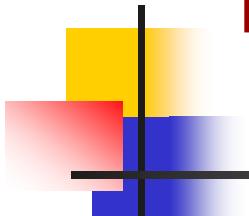
- The area above the waterline
- highly-oxygenated acts as the cathodic and is
- completely unaffected by corrosion.

- However, if the water is relatively free from acidity, little corrosion takes place.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- The problem of waterline corrosion is also that **concerns marine engineers**.
- In the case of ships, this kind of corrosion is often
- **accelerated by marine plants** attaching themselves to the sides of ships.
- The use of **special antifouling paints restrict this to some extent**.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- It is characterized **by a highly localized attack occurring**, when overall corrosion is negligible. For stress corrosion to occur :
 - (i) **presence of tensile stress**, and
 - (ii) a specific corrosive environment are necessary.

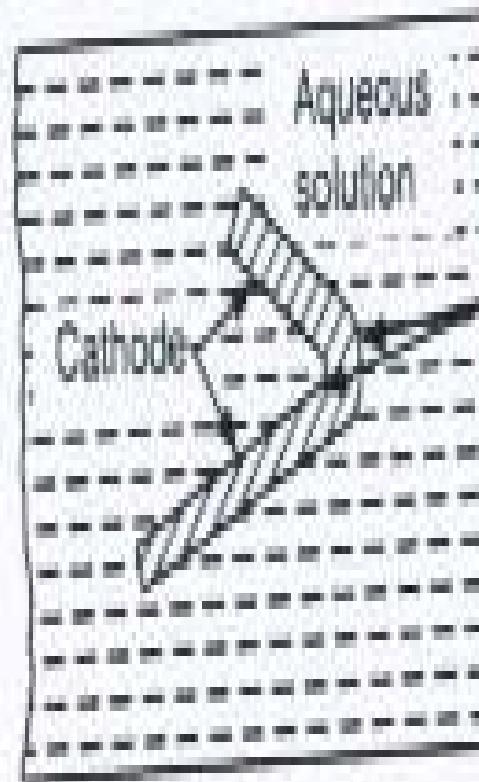
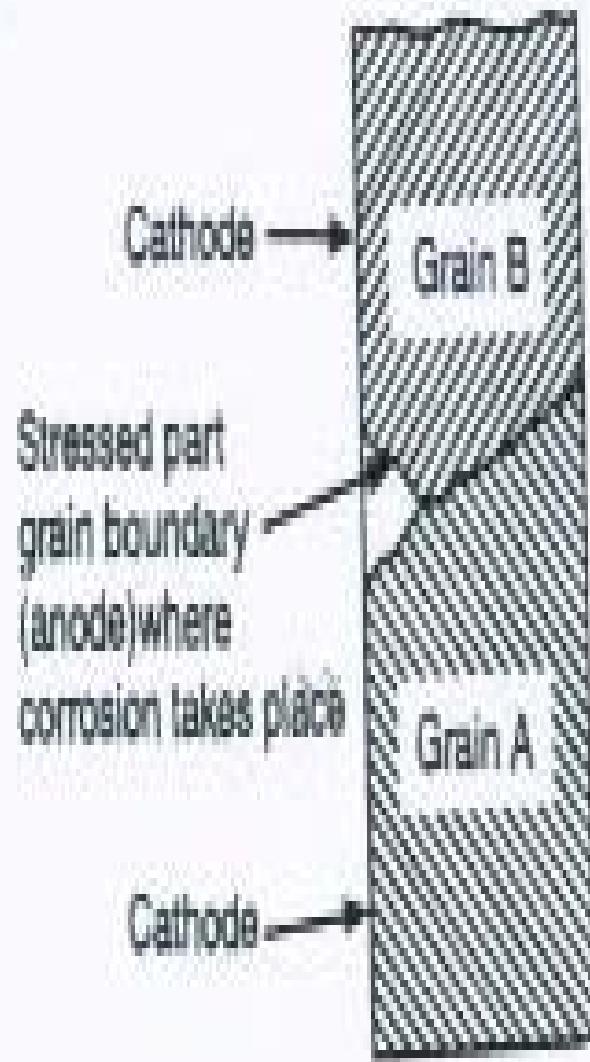
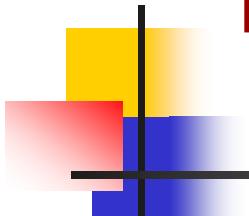


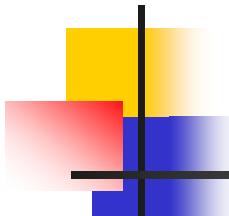
Fig. 17. Stress corrosion.



L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

The corrosive agents are highly specific and selective such are:

- (a) caustic alkalis and strong nitrate solution for mild steel;
- (b) traces of ammonia for brass;
- (c) acid chloride solution for stainless steel.

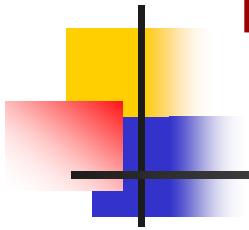


L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

This type of corrosion is seen in fabricated articulated articles of certain alloys

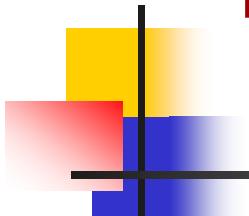
like **high-zinc brasses and nickel brasses** due to the

- presence of stresses caused by heavy working like
- **rolling, drawing or insufficient annealing.**
- However, pure metals are relatively immune to stress corrosion.



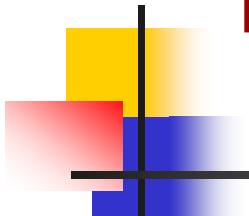
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- These become so chemically- active that they are attacked,
- even by a mild corrosive environment, resulting in the formation of a crack
- which grows and propagates in a plant (perpendicular to the operating tensile stress),



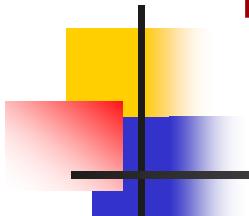
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- which grows and propagates in a plant
- perpendicular to the operating tensile stress,
- until failure occurs or it may stop, after progressing a finite distance.
- Some typical examples



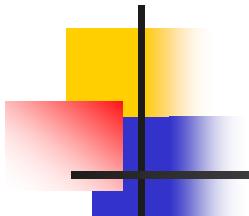
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- V(1) Season cracking in a term applied to stress corrosion of copper alloys, mainly brasses.
- Pure copper is immune to stress corrosion, but
- presence of small amounts of alloying element (like P,As,Sb, Zn, Al, Si) result in marked sensitivity.



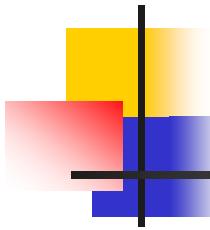
L-24 PITTING, WATERLINE, UNDERGROUND & STRESS CORROSION

- For example,
- alpha brass (which when highly stressed) undergo intergranular cracking in an atmosphere,
- containing traces of ammonia or amines.
- The attack occurs along the grain boundaries,
- which become more anodic with respect to the grain themselves (probably



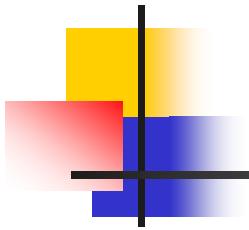
Lect . -25 PASSIVITY

- . Passivity is the
- “phenomenon in which a metal or an alloy exhibits a much higher corrosion - resistance than expected from its position in the electrochemical series.”



Passivity falling order

Tl -----> Al -----> Cr -----> Be --
-->Mo -----> Mg -----> Ni --
-->Co -----> Fe -----> Mn -----> Zn --
--> Cd -----> Sn -----> Pb -----> Cu



- The action of more concentrated
- solution of HNO_3 on active metals (Fe and Al) **produces a thin protective oxide film,**
- thereby **stifling** the anodic reaction and making them passive

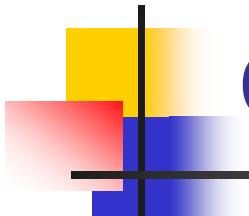
L-25 micro-biological corrosion

& Fatigue. Theories of corrosion

In water-logged soils,

- the amount of free oxygen available is very small,
- but various bacteria and micro-organisms can grow,
- which may lead to **micro-biological corrosion**.

L-26 Factors affecting corrosion

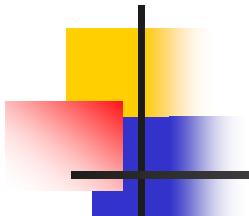


corrosion depends

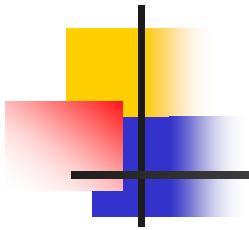
- (i) the pH (or acidity) of the soil,
- (ii) the presence of salt, and
- (iii) the presence of oxygen, etc.

oxygen facilitates the evolution of hydrogen and, hence, accelerates the rate of attack.

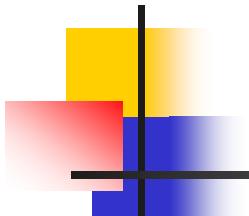
INTERGRANULAR CORROSION



- **along grain boundaries and only where the material, especially sensitive to corrosive attack exists,**
- **and corrosive liquid possesses a selective character of attacking only at the grain boundaries,**

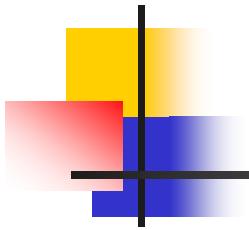


- but leaving the grain interiors
- untouched or
- only slightly attacked.



L-26 Protective measures against corrosion

- Modification of the properties of the metal
- Prevention of corrosion by material selection & design
- Modification of the environment
- Other methods



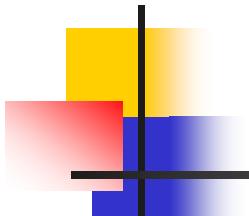
L-26 Protective measures against corrosion

- i) Modification of the properties of the metal

1. Alloying : Platinum ,Gold are noble metals

These are corrosion resistant

The corrosion resistance property will be increased by alloying suitable element



L-26 Protective measures against corrosion

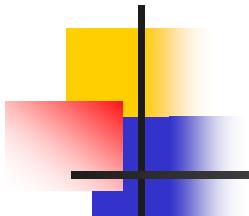
Good corrosion resistance is possible by adding homogenous alloy

Chromium is the best metal for alloying steel or iron

Because the film made is **self healing**

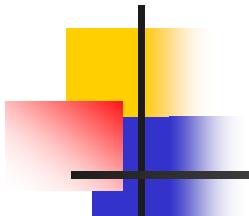
- More important is -chromium is

passive in nature



L-26 Protective measures against corrosion

- Steel possessing **13% Cr is used in surgical instruments.**
- Iron alloys which has **13-25% Cr is used in turbines brackets, heat resistant parts.**
- This alloy is **called ferrite stainless steels**

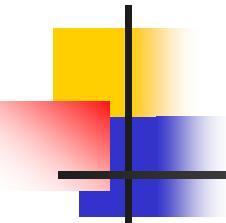


L-26 Protective measures against corrosion

2. Using pure metal :

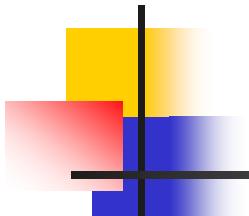
Pure metal is always corrosion resistant

For ex: any pure metal



% of purity	99.999	99.99	99.95	99.0
Corrosion rate	1	2650	5000	7200

This is seen in Zinc

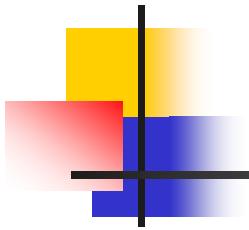


L-26 Protective measures against corrosion

3. Use of protective coatings :

Anodic coatings

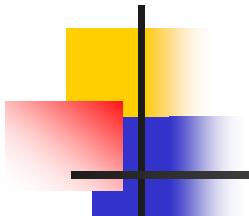
Cathodic coatings



L-26 Protective measures against corrosion

- ANODIC COATINGS
- In this ,the metal used for coating is **more anodic**
- Anodic coatings protect the underlying base metal
- For ex: **coating of Al, Cd & Zn on steel surface**

L-26 Protective measures against corrosion



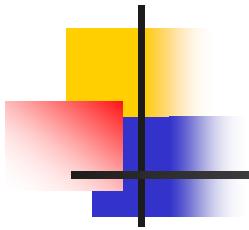
Protective Coatings

Anodic coatings

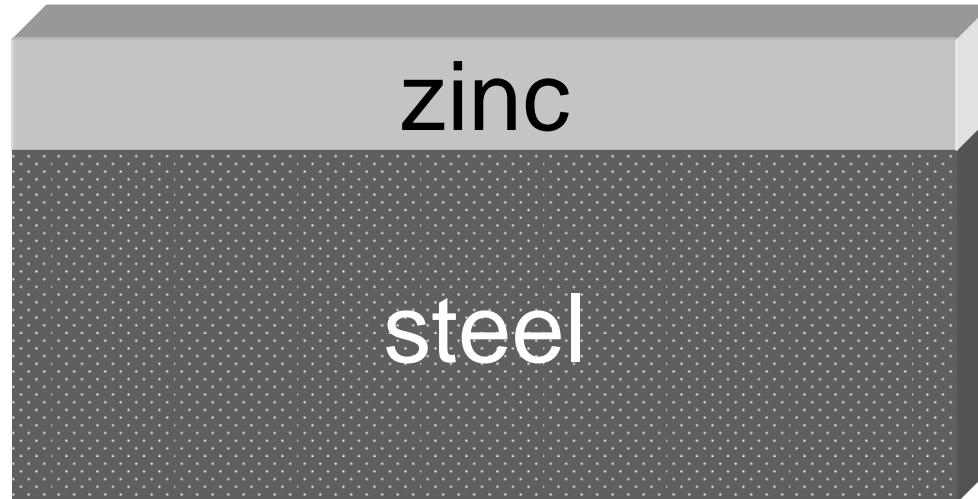
zinc being more anodic
will get attacked

It protects iron /steel under it

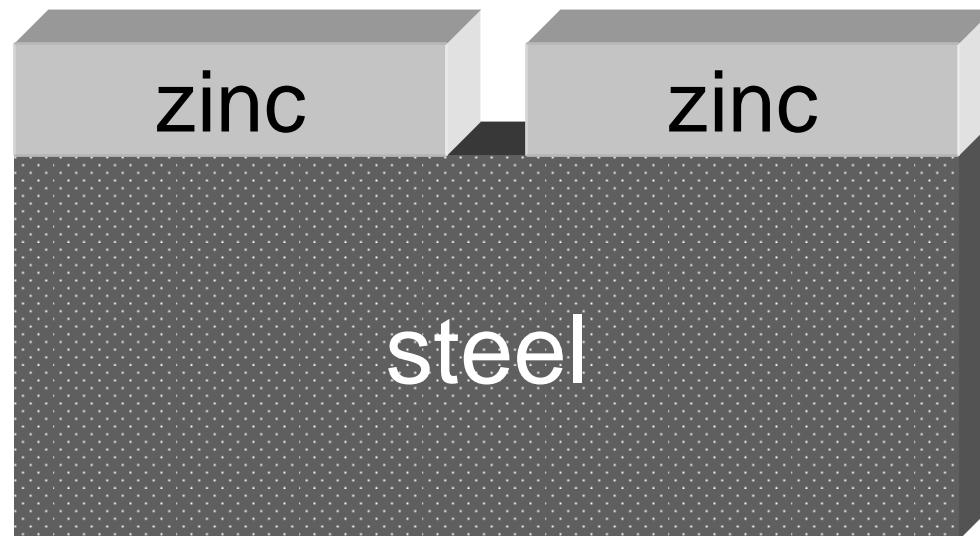
Here steel works as cathode

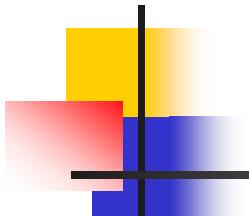


For example coating of tin on iron



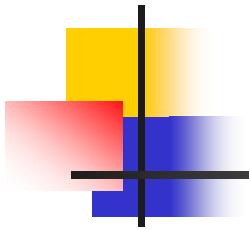
L-26 Protective measures against corrosion





L-26 Protective measures against corrosion

- By chance even if pores or breakages are seen ,still steel will not get corroded
- Because of coating of zinc

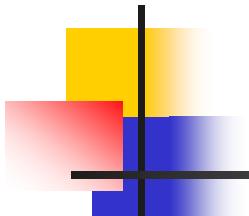


L-26 Protective measures against corrosion

■ Cathodic coatings

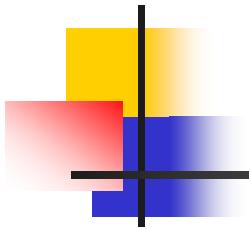
- These coatings protect the underlying base metal by the

higher corrosion resistant character



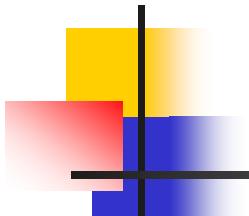
L-26 Protective measures against corrosion

- Here the good protection is possible only with plane surface ,
- Not at all with any breakages or pores
- **If pores are seen ,the corrosion will be speeded up**



For example coating of tin on iron



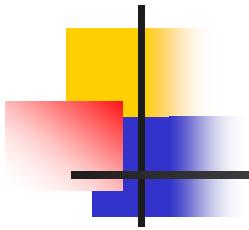


L-26 Protective measures against corrosion

4. Refining : As stainless possess
P, S & C

There is a chance of corrosion

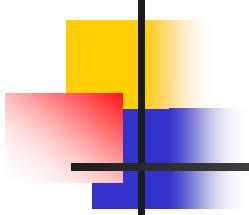
Refining is a process to lower quantities
of above said elements



L-26 Protective measures against corrosion

5. Annealing :

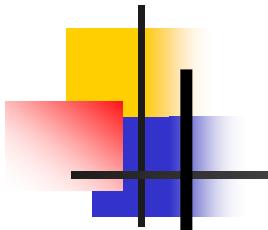
this is a process to relieve the metal from stresses by heating



L-26 Protective measures against corrosion

- ii) Prevention of corrosion by material selection & design
 - Design & material selection principles
 - Avoid L, T, & U shaped profiles in construction

Because this may cause corrosion



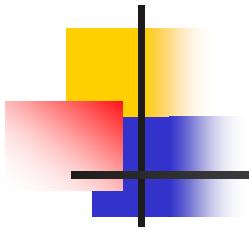
welding



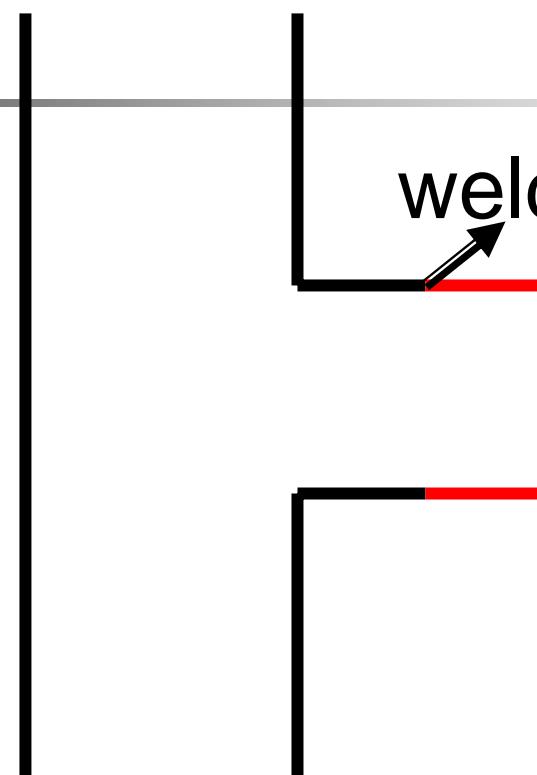
welding

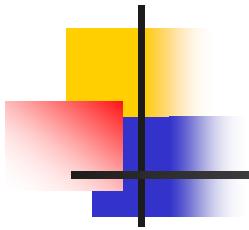
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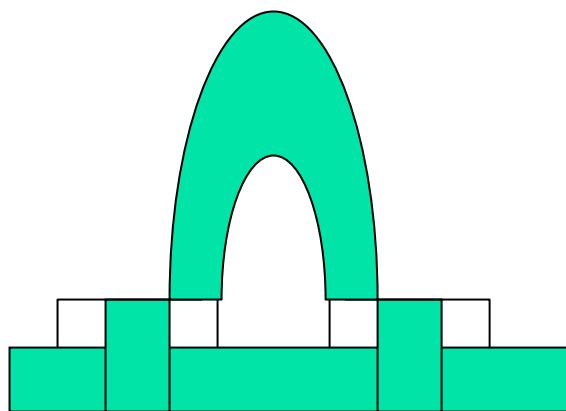
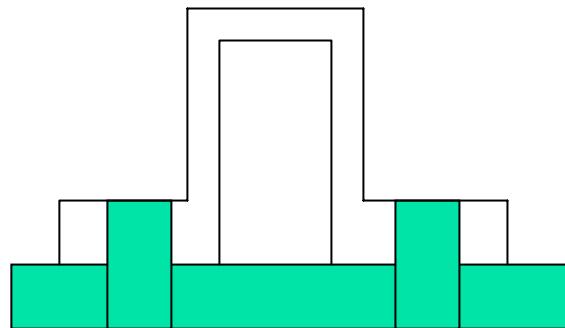


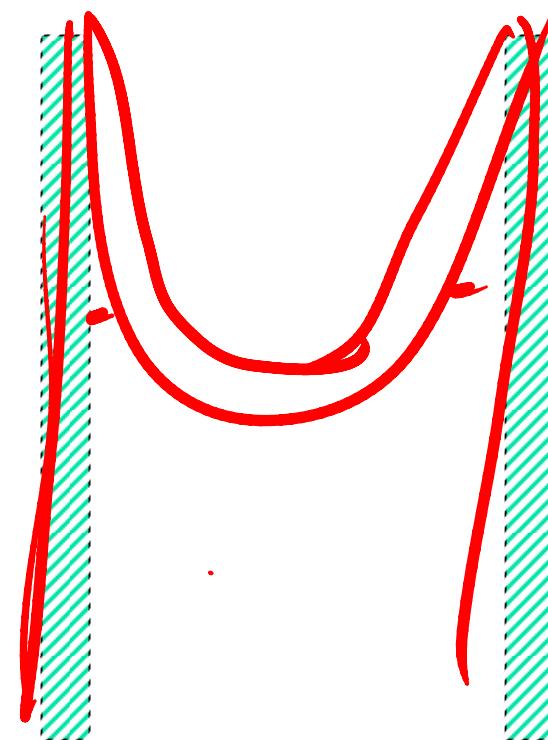
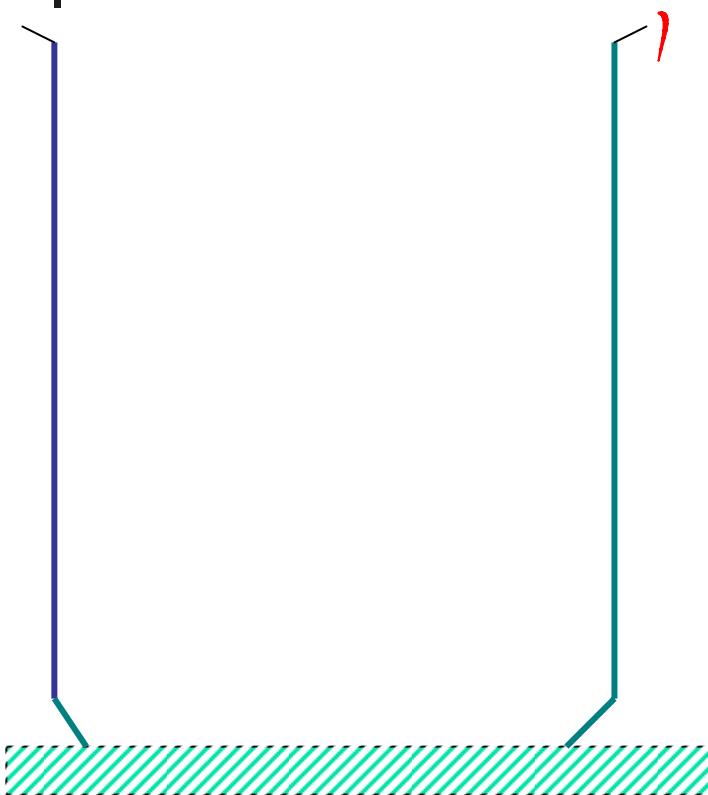
welding

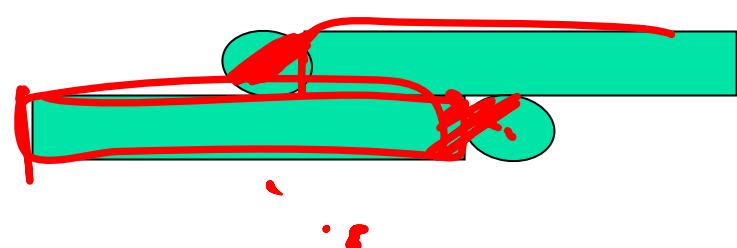
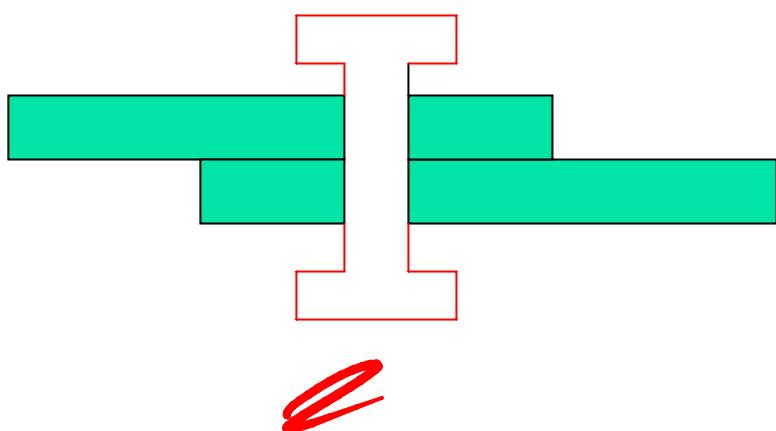


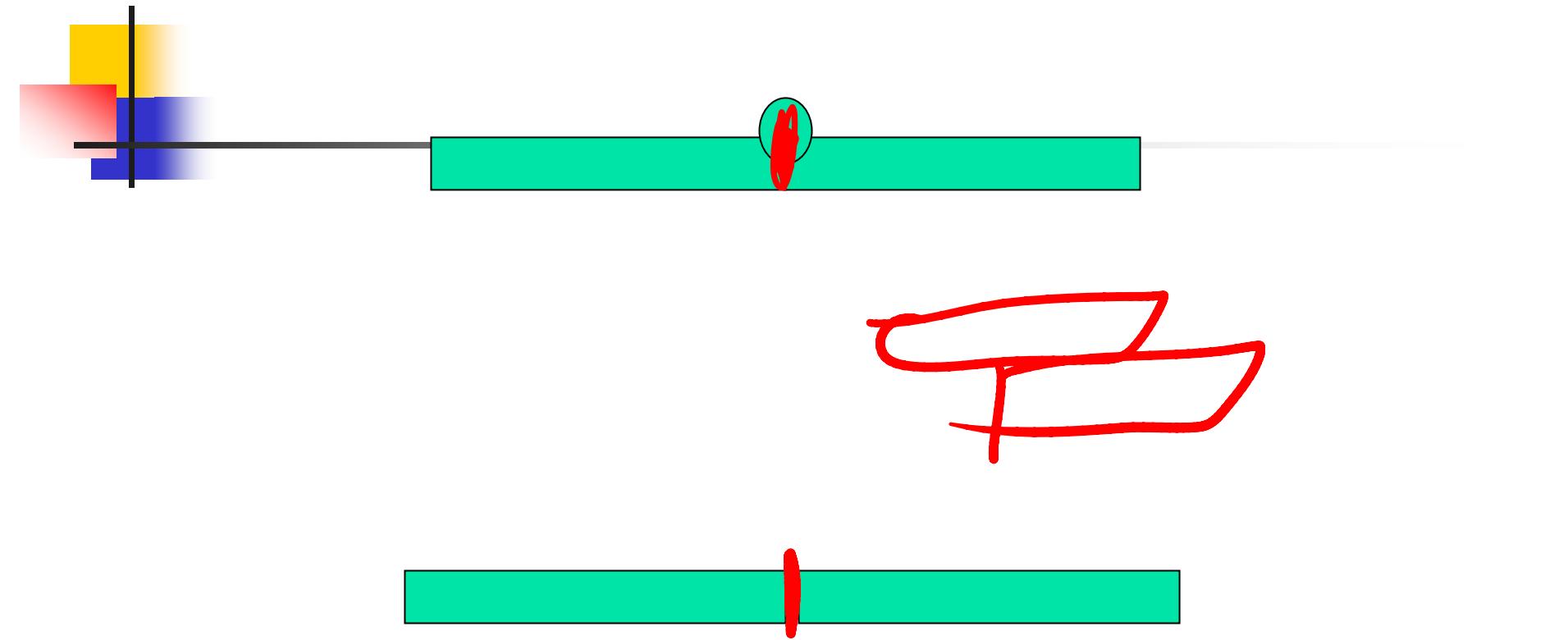


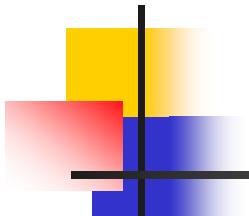
Water slips from here
Water stands here











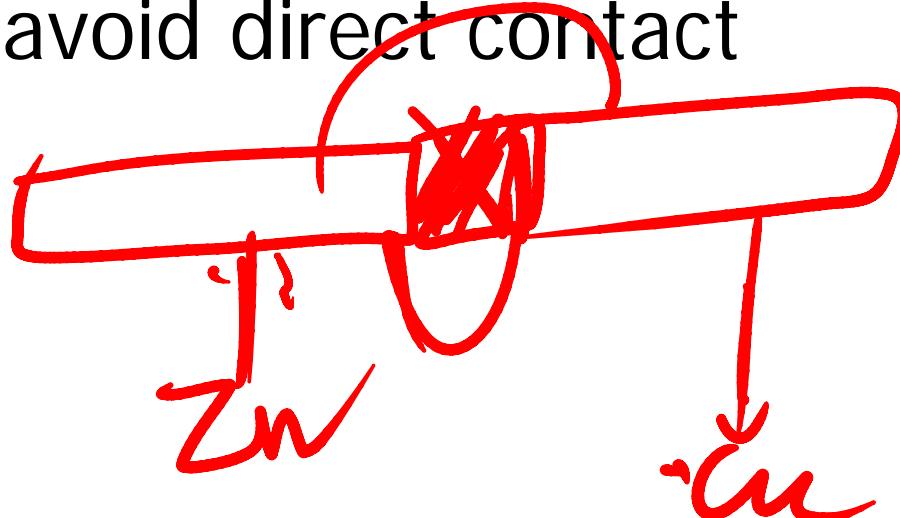
L-26 Protective measures against corrosion

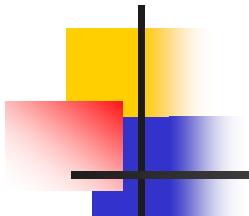
- General facts about designing
- Avoid the contact of dissimilar metals in the presence of a corroding solution.
- If at all 2 dissimilar metals are in contact, they should be as close as possible in electrochemical series.

L-26 Protective measures against corrosion

- When ever direct contact of 2 dissimilar metals is must

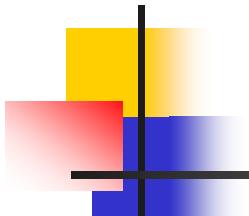
An insulating fitting may be made to avoid direct contact





L-26 Protective measures against corrosion

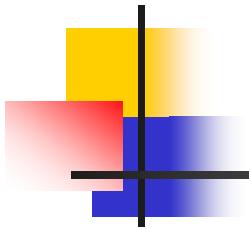
- If 2 dissimilar metals are supposed to be in contact the anodic area should be made larger
- The anode metal should not be painted to avoid breakages



L-26 Protective measures against corrosion

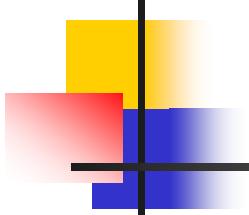
iii) Modification of the Environment

- Corrosive nature can be reduced by 2 methods
 1. by the removal of harmful constituents
 2. by the addition of specific substances ,which neutralize the corrosive environment



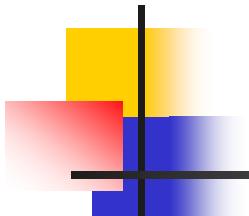
L-26 Protective measures against corrosion

- De aeration
- De activation
- Dehumidification
- Alkaline neutralization



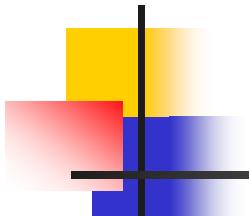
L-26 Protective measures against corrosion

- De aeration
- consider oxygen concentration type of corrosion
- Here elimination of oxygen from aqueous solution reduces metal corrosion



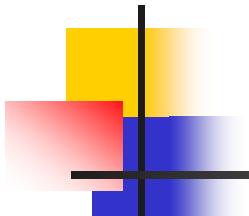
L-26 Protective measures against corrosion

- removal of dissolved oxygen is done by adjustment of temperature & by mechanical shakeup
- This method also reduces the CO_2
- This treatment will decrease the corrosion rate in steel pipes carrying steam condensates from boilers



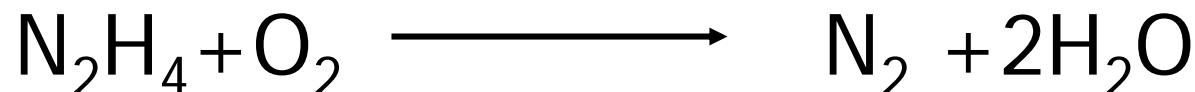
L-26 Protective measures against corrosion

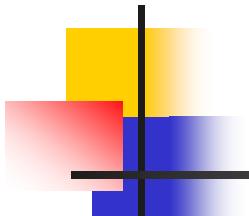
- Deactivation
- This involves the addition of chemicals , which can combine with the oxygen in aqueous solution.
- Sodium sulphite (Na_2SO_3)



L-26 Protective measures against corrosion

- $2 \text{Na}_2\text{SO}_3 + \text{O}_2 \longrightarrow 2\text{Na}_2\text{SO}_4$
- Hydrazine is good over sodium sulphite

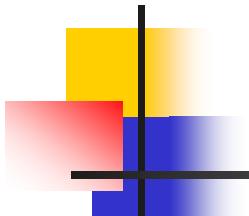




L-26 Protective measures against corrosion

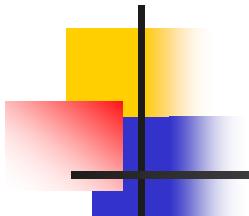
Dehumidification

- This process reduces the moisture content of air to such a level that condensation of water on surface of the metal should be so small.
- Alumina & silica gels , preferably adsorb the moisture from their surfaces
- That is why they are used in closed containers (air conditioning)



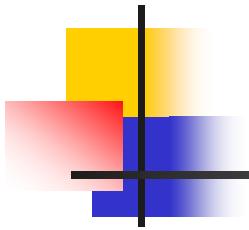
L-26 Protective measures against corrosion

- Alkaline neutralization
- This is meant to control acidic condition to avoid corrosion
- Acidity includes the presence of $\text{H}_2\text{S}, \text{HCl}, \text{CO}_2, \text{SO}_2$ etc
- Alkaline neutralizers are used to control corrosion
- These are ammonia , sodium hydroxide etc



L-26 Protective measures against corrosion

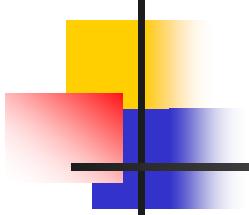
- These are generally injected in the form of liquid or vapour to the corroding system.
- This is applicable in refinery industries.



L-26 Protective measures against corrosion

iii) Others

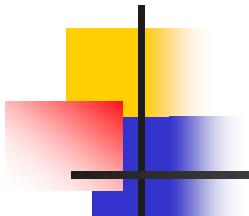
- Using inhibitors
- Metal cladding
- Electroplating
- Painting
- Plastic coating



L-26 Protective measures against corrosion

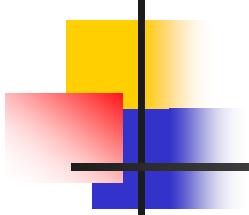
Inhibitors

- Anodic inhibitors
- Cathodic inhibitors



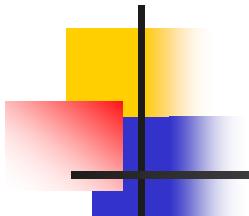
L-26 Protective measures against corrosion

- Anodic inhibitors
- Alkalies ,molybdates ,phosphates , chromates are used as inhibitors
- The above chemicals react with the ions of the anode &form insoluble precipitates



L-26 Protective measures against corrosion

- These precipitates form as a protective layer on metal surface
- This layer acts as barrier



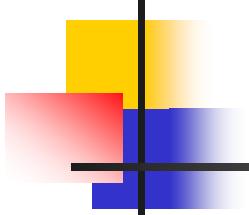
L-26 Protective measures against corrosion

- Cathodic inhibitors
- In acidic solutions the reaction is
- $$2\text{H}^+ + 2\text{e}^- \longrightarrow \text{H}_2$$
- Corrosion can be reduced by slowing down the diffusion rate of hydrogen ion

L-26 Protective measures against corrosion

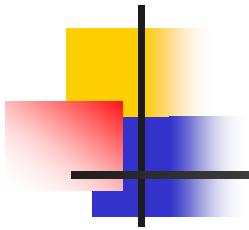
- increasing over voltage of hydrogen evolution type
- diffusion of Hydrogen ions can also be decreased by using organic inhibitors like amines
- In neutral solutions ,the cathodic reaction is of absorption of oxygen type

$$\frac{1}{2}\text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \longrightarrow 2\text{OH}^-$$



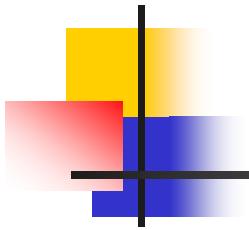
L-26 Protective measures against corrosion

- Metal cladding
- Metal cladding is a process



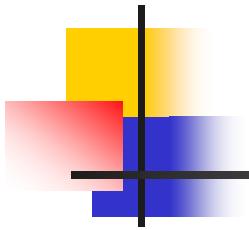
L-26 Protective measures against corrosion

- Electroplating



L-26 Protective measures against corrosion

- Painting



L-26 Protective measures against corrosion

- Plastic coating

L-27 Batteries & Battery technology

Primary cells

Cell

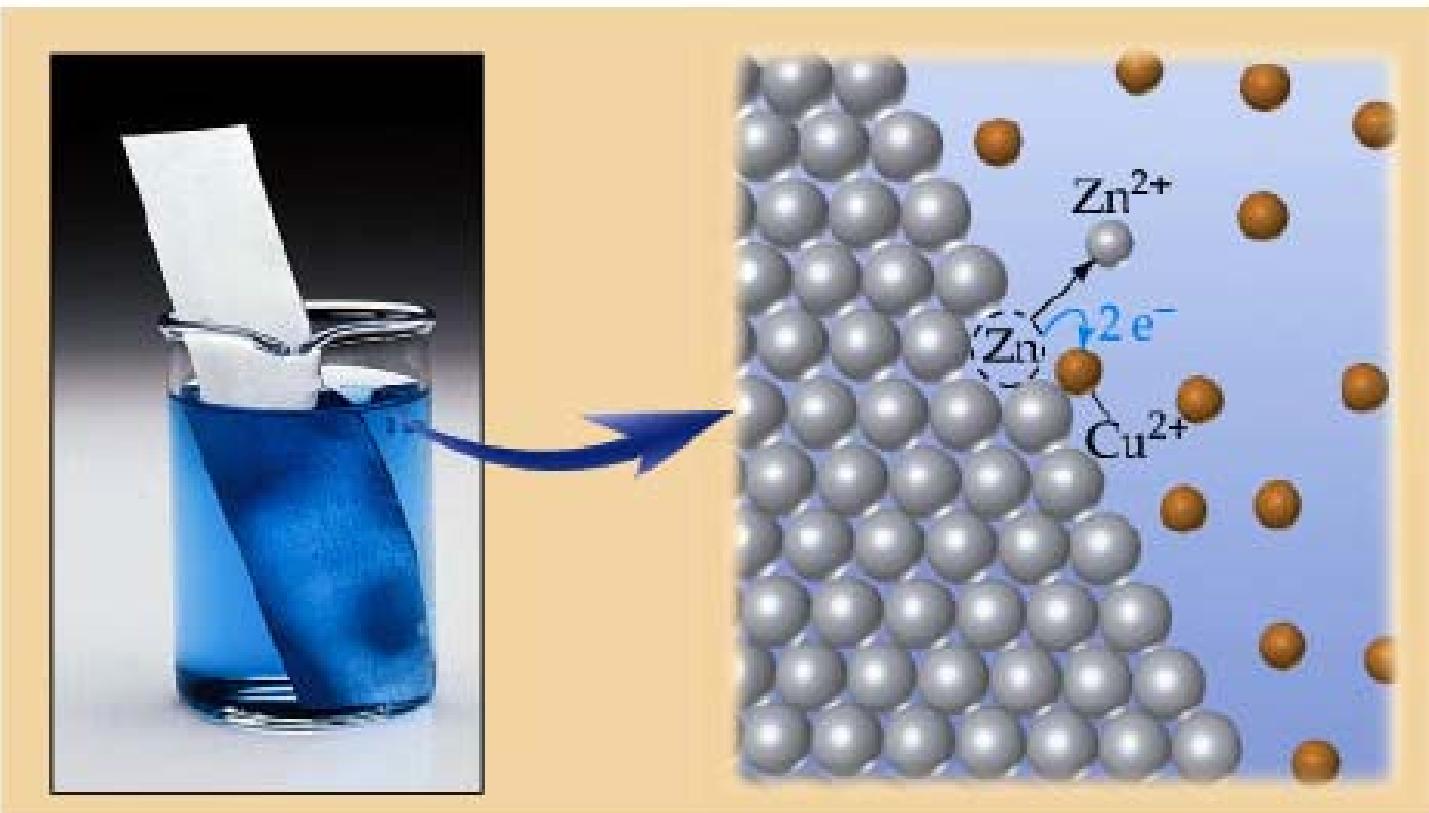
A cell is a single arrangement

of two electrode and an electronic solution

capable of yielding electricity.

Redox Reactions

- **Oxidation Half-Reaction:** $\text{Zn(s) } \rightarrow \text{Zn}^{2+}(aq) + 2 e^-$.
- The Zn loses two electrons to form Zn^{2+} .



L-27 Batteries & Battery technology

Primary cells

Electrodes

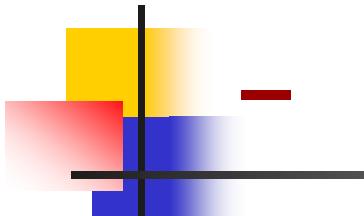
Anode

Liberates electrons
Oxidizing electrodes

Cathode

absorbs electrons
Reducing electrodes

L-27 Batteries & Battery technology



Primary cells

Batteries

Combination of two or more cells

**Or galvanic cells ,
electrically connected
arranged in series**

L-27 Batteries & Battery technology – ELECTROCHEMICAL CELL

- *An electrochemical cell is a device in which a redox reaction is utilized to get electrical energy.*
- An electrochemical cell is also referred to as voltaic or galvanic cell.

L-27 Batteries & Battery technology – ELECTROCHEMICAL CELL

- The electrode where oxidation occurs, is called anode; while
- the electrode where reduction occurs, is called cathode.

Cell / Batteries

Primary cell secondary cell others

→ Daniel cell

→ Dry cell or
Lachlanche cell

→ Weston standard
cadmium

→ Alkaline battery

→ Mercury battery

→ Lead acid
storage battery

→ Alkaline
storage battery

Ni, Cd

Silver oxide &
Zn cell

→ Reserve cell

→ Fuel cell

L-27 Batteries & Battery technology

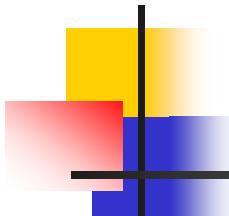
Primary cells

Primary Cell

Cell reaction is irreversible

The reactants of most part been converted to product

*No more electricity is produced
Battery is almost dead*

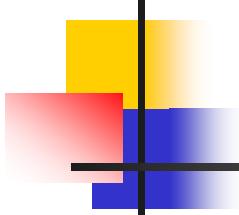


L-27 Batteries & Battery technology

Secondary battery (or secondary cells) in which

the cell reaction can be **reversed by passing direct electric current** in opposite direction. Thus,

a secondary battery may be used through a large number of cycles of discharging and charging.



L-27 Batteries & Battery technology

Flow battery and fuel cell, in which materials (reactants, products, electrolytes) pass through the battery,

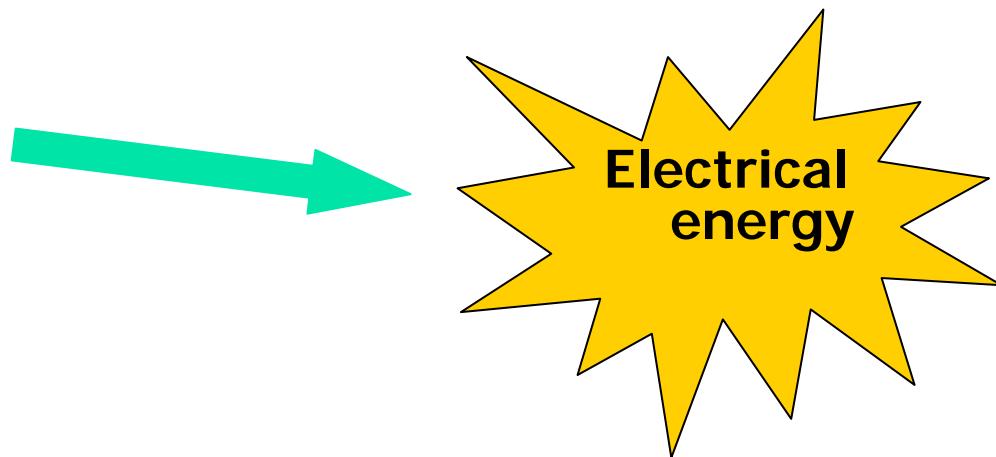
which is simply an electrochemical cell that **converts chemical energy to electrical energy**.

L-27 Batteries & Battery technology

Primary cells

(i) Daniel cell / electrochemical / voltaic cell

Chemical energy



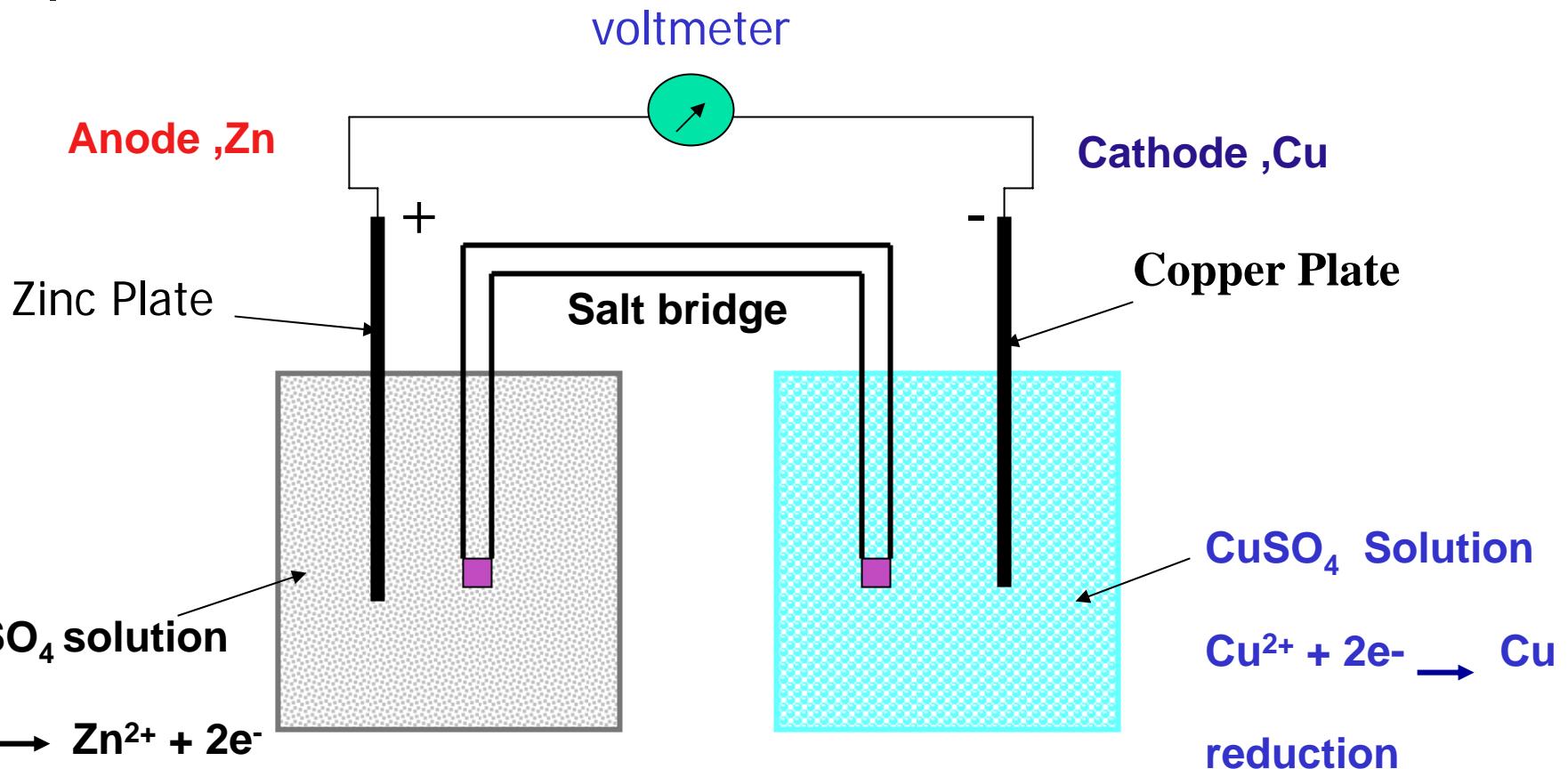
L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

- *An electrochemical cell is a device in which a redox reaction is utilized to get electrical energy.*
An electrochemical cell is also referred to as **voltaic or galvanic cell**.
- The electrode where **oxidation** occurs, is called **anode**;
- while the electrode where **reduction** occurs, is called **cathode**.

Primary cells

Galvanic / Daniel Cell



L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical /voltaic cell

- **DANIEL CELL** is an electrochemical or galvanic cell. It consists of
- **zinc** electrode (*anode*), dipped in ZnSO_4 solution (where ***oxidation*** takes place) and
- a **copper** electrode (*cathode*) dipped in CuSO_4 solution (where ***reduction*** takes place).

L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

- In other words each electrode is a half cell.
- The two solutions are *separated by a salt bridge* .
- through which the salt solutions can seep and come in contact naturally

L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

Chemical reaction

Anodic reaction [Oxidation]



Cathodic reaction [Reduction]



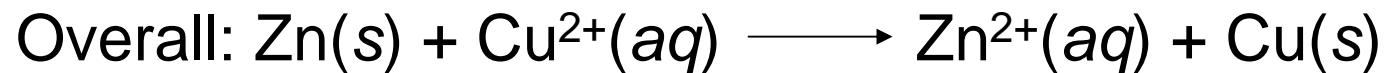
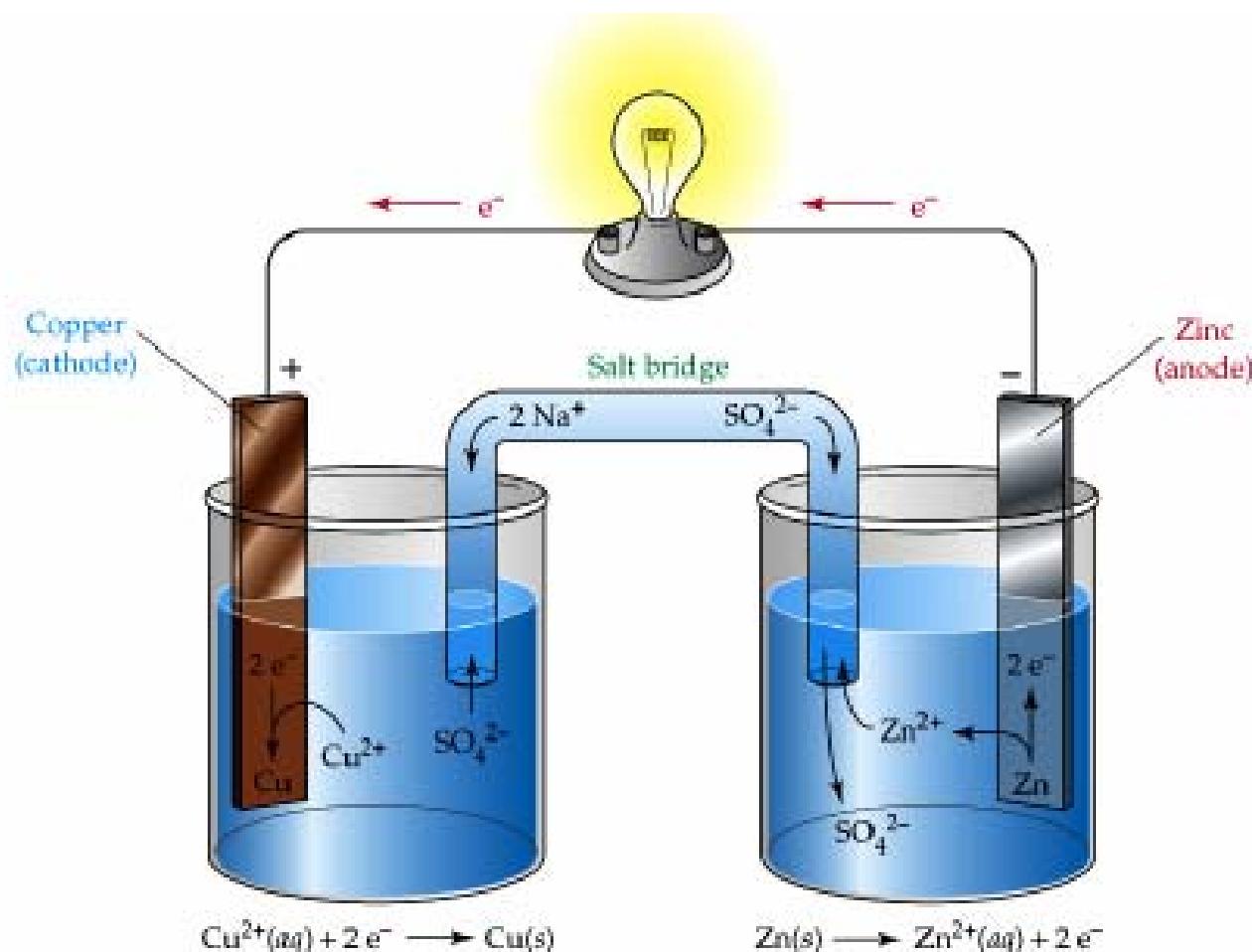
L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical /voltaic cell

Over all reaction



Redox Reactions



L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

- The tendency of Zn to form Zn^{2+} is greater than
- the tendency of Zn^{2+} to get deposited as Zn and hence
- the zinc metal acquires a negative charge.

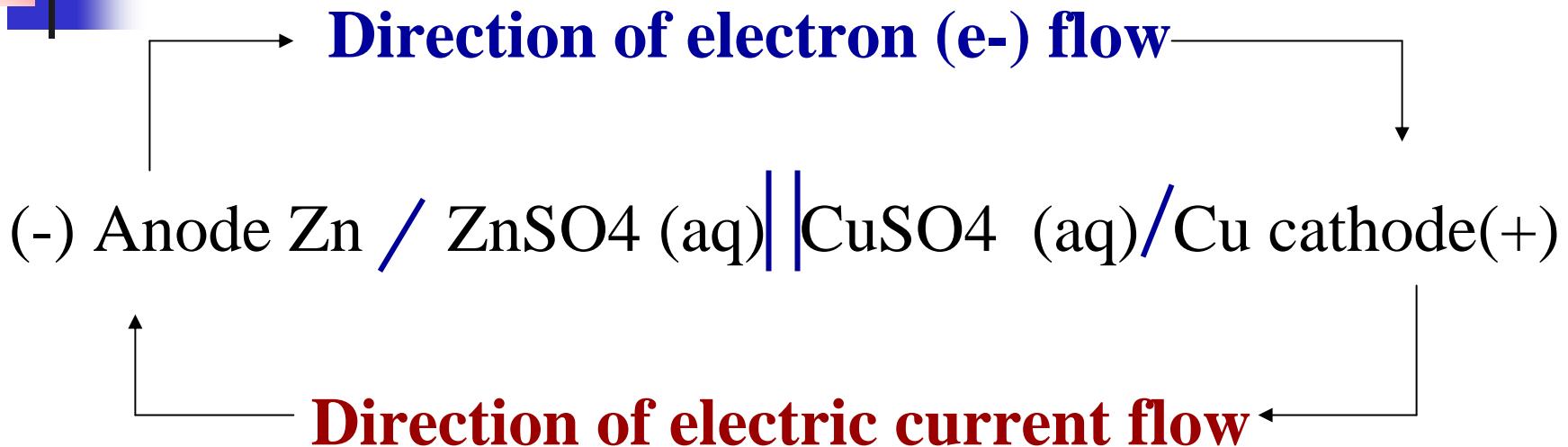
L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

- Opposite is true for Cu metal and thus
- copper electrode becomes positively charged.
- The e.m.f. of the cell is 1.1Volts.

L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical /voltaic cell



L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical /voltaic cell

L-27 Batteries &..... Primary cells

i) Daniel cell / electrochemical / voltaic cell

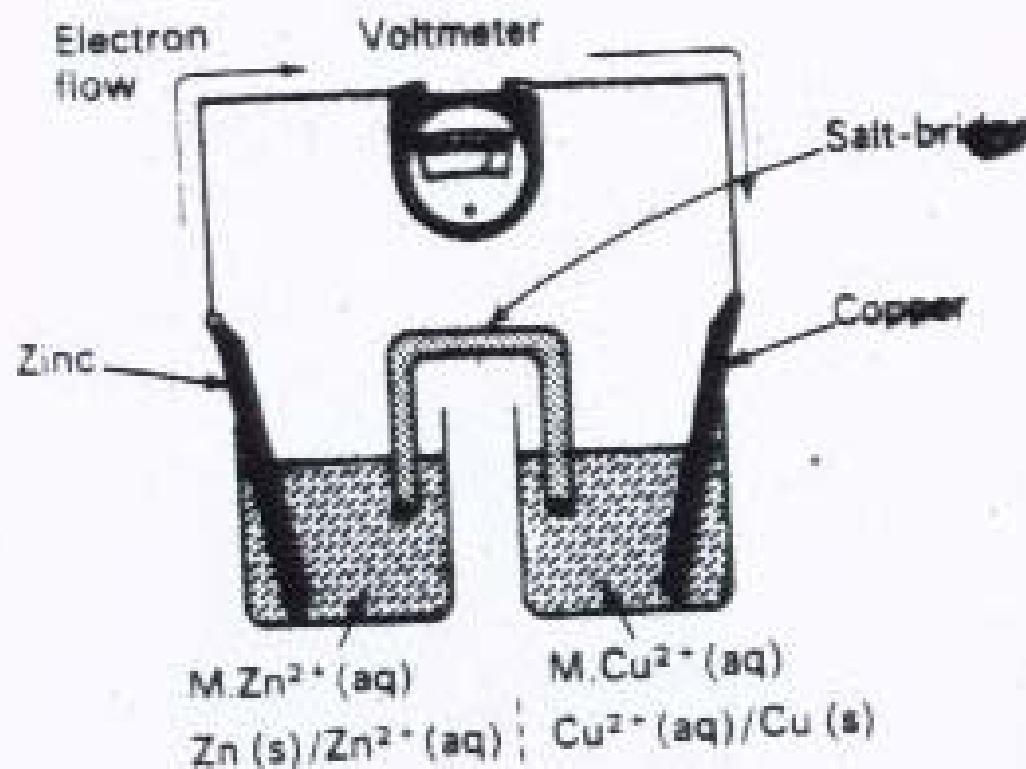
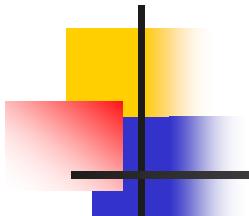


Fig. 5. Daniel cell.



L-27 Batteries & Battery technology

Primary cells

(ii) Dry (or Laclanche) cell, i.e.,

- a cell without fluid component is perhaps the most familiar of all batteries.
- The anode of the cell is a zinc can (or container)

L-27 Batteries & Battery technology

Primary cells

(ii) Dry (or Laclanche) cell,

The anode of the cell is a zinc can (or container) containing

- an electrolyte consisting of NH_4Cl , ZnCl_2 and MnO_2 to which
- starch is added to make it thick paste-like so that it is less likely to leak.

L-27 Batteries & Battery technology

Primary cells

(ii) Dry (or Laclanche) cell,

The anode of the cell is zinc can (or container)

A carbon (graphite) rod serves as the cathode, which is immersed in the electrolyte in the centre of the cell.

L-27 Batteries & Battery technology –

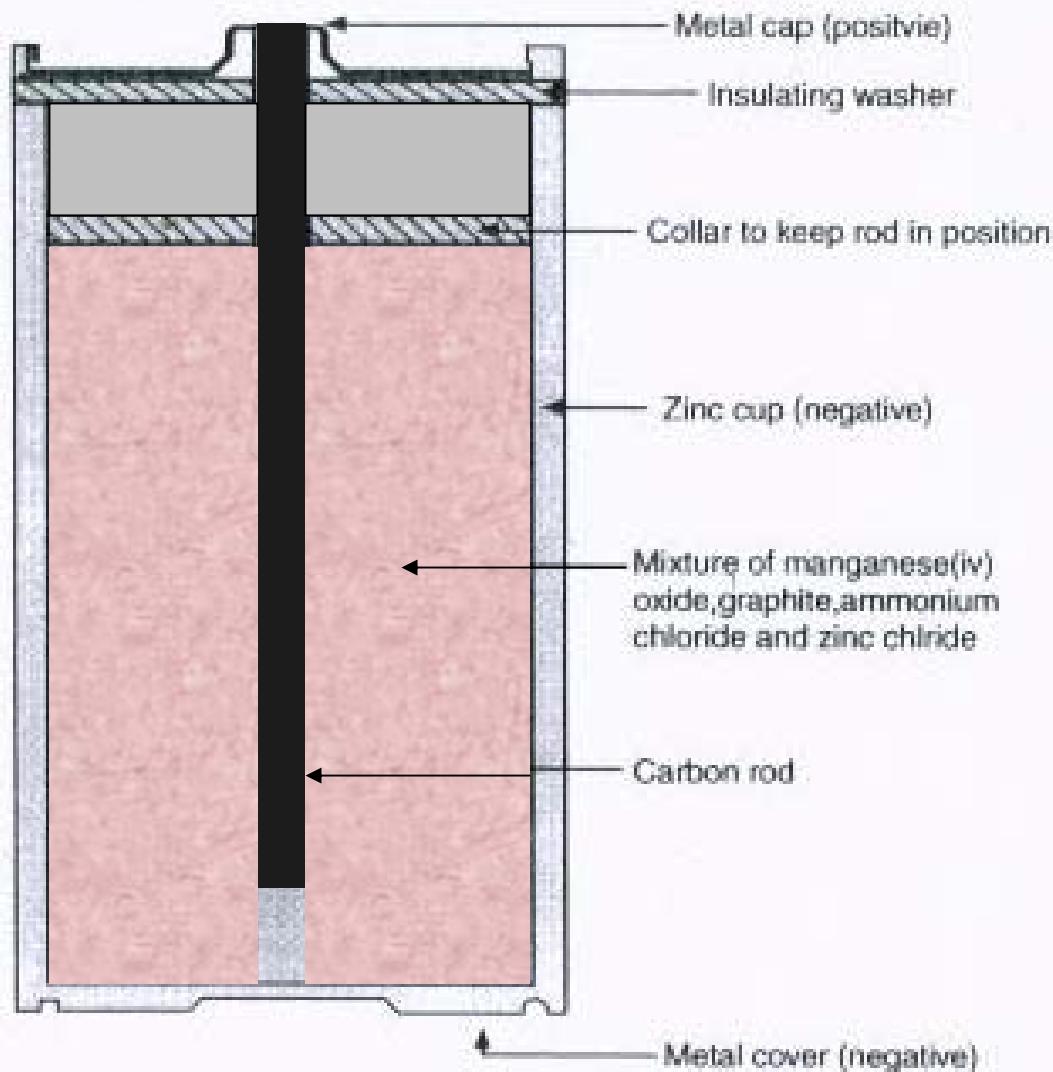


Fig. 15. Construction of a dry cell.

L-27 Batteries & Battery technology

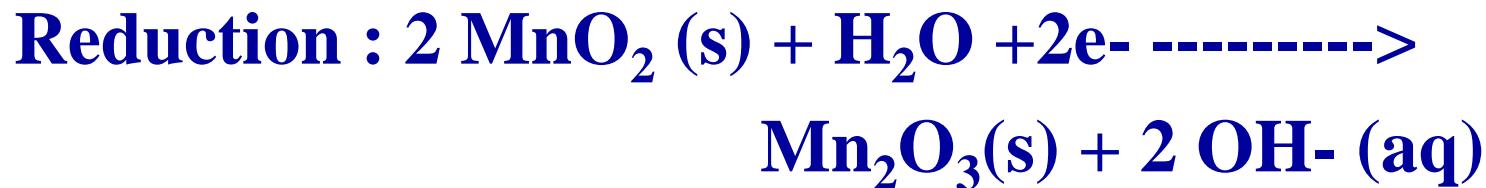
(ii) Dry (or Laclanche) cell, [primary]

- The anode (oxidation) half-reaction is :
- Oxidation : $\text{Zn(s)} \longrightarrow \text{Zn}^{2+} \text{ (aq)} + 2\text{e}^-$
(At anode)

L-27 Batteries & Battery technology

(ii) Dry (or Laclanche) cell, [primary]

The cathode (reduction) reaction is quite complex. Essentially, it involves the reduction of MnO_2 to a series of compounds having Mn in + 3 oxidation state, For example, Mn_2O_3 .



L-27 Batteries & Battery technology

(ii) Dry (or Laclanche) cell, [primary]

- However, an acid-base reaction between OH^- and NH_4^+ (derived from NH_4Cl) evolves $\text{NH}_3(\text{g})$, which disrupts the current flow.
- $\text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \longrightarrow \text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l})$
- This is prevented by a reaction of $\text{NH}_3(\text{g})$ with Zn^{2+} (from ZnCl_2) to form the complex ion $[\text{Zn}(\text{NH}_3)_2]\text{Cl}_2(\text{s})$.

L-27 Batteries & Battery technology

(ii) Dry (or Laclanche) cell, [primary]

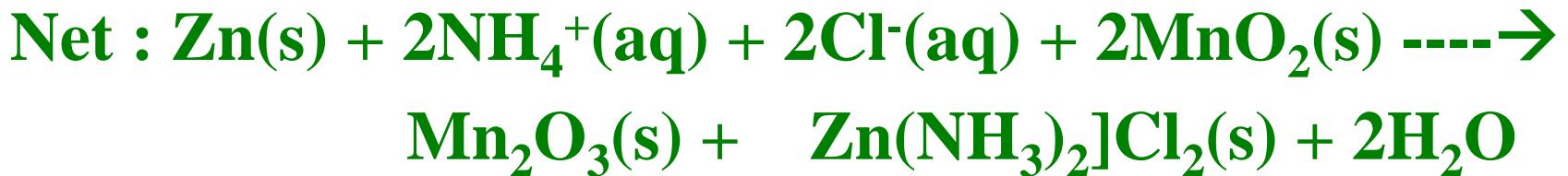
- Hence, the reactions at two electrodes are :
- Anode : $\text{Zn(s)} \rightarrow \text{Zn}_2^+(aq) + 2e^-$
- cathode : $2\text{MnO}_2(s) + 2\text{NH}_4^+(aq) + 2e^- \rightarrow \text{Zn}(\text{NH}_3)_2\text{Cl}_2(s)$
- Net : $\text{Zn(s)} + 2\text{NH}_4^+(aq) + 2\text{Cl}^-(aq) + 2\text{MnO}_2(s) \rightarrow \text{Mn}_2\text{O}_3(s) + \text{Zn}(\text{NH}_3)_2\text{Cl}_2(s) + 2\text{H}_2\text{O}$!!!!

- Hence, the reactions at two electrodes are :



- Reduction :

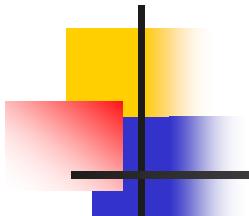
- $2 \text{MnO}_2 \text{ (s)} + \text{H}_2\text{O} + 2\text{e}^- \longrightarrow \text{Mn}_2\text{O}_3\text{(s)} + 2 \text{OH}^- \text{ (aq)}$
- $\{ \text{NH}_4^+ \text{ (aq)} + \text{OH}^- \text{ (aq)} \longrightarrow \text{NH}_3 \text{ (g)} + \text{H}_2\text{O(l)} \} \times 2$
- $\text{Zn}^{2+} \text{ (aq)} + 2\text{NH}_3\text{(aq)} + 2\text{Cl}^- \longrightarrow \text{Zn}(\text{NH}_3)_2\text{Cl}_2\text{(s)}$



L-27 Batteries & Battery technology

(ii) Dry (or LaClanche) cell, [primary]

- The dry cell is a primary cell, since the reactions involved cannot be reversed back by passing electricity through the cell.
- *Advantages*
 - i) Dry cell is cheap to make.
 - ii) It gives a voltage of about 1.5 V.



L-27 Batteries & Battery technology

(ii) Dry (or Laclanche) cell, [primary]

- *Disadvantages*
 - i) When current is drawn rapidly from it, **there is drop in voltage** due to products built up on the electrodes.
 - ii) Since the electrolytic **medium is acidic**, **so zinc metal dissolves** slowly, even if it is not in use.

L-27 Batteries & Battery technology

(ii) Dry (or Laclanche) cell, [primary]

Uses

Dry cells are used in

- **flash lights, transistor radios,**
- **calculators etc.**

L-27 Batteries & Battery technology

Primary cells

Salt bridge

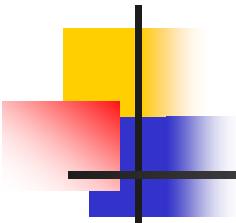
Inverted U tube structure

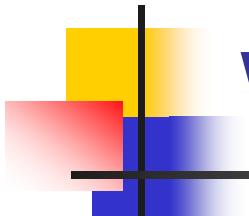
filled with aqueous solution of

electrolyte KCl , KNO_3 , K_2SO_4

+

Gelatin ,agar agar solution





Weston Standard cadmium cell

- Capable of giving constant & reproducible e.m.f. &
- has a negligible temperature coefficient
- Source of unvarying potential

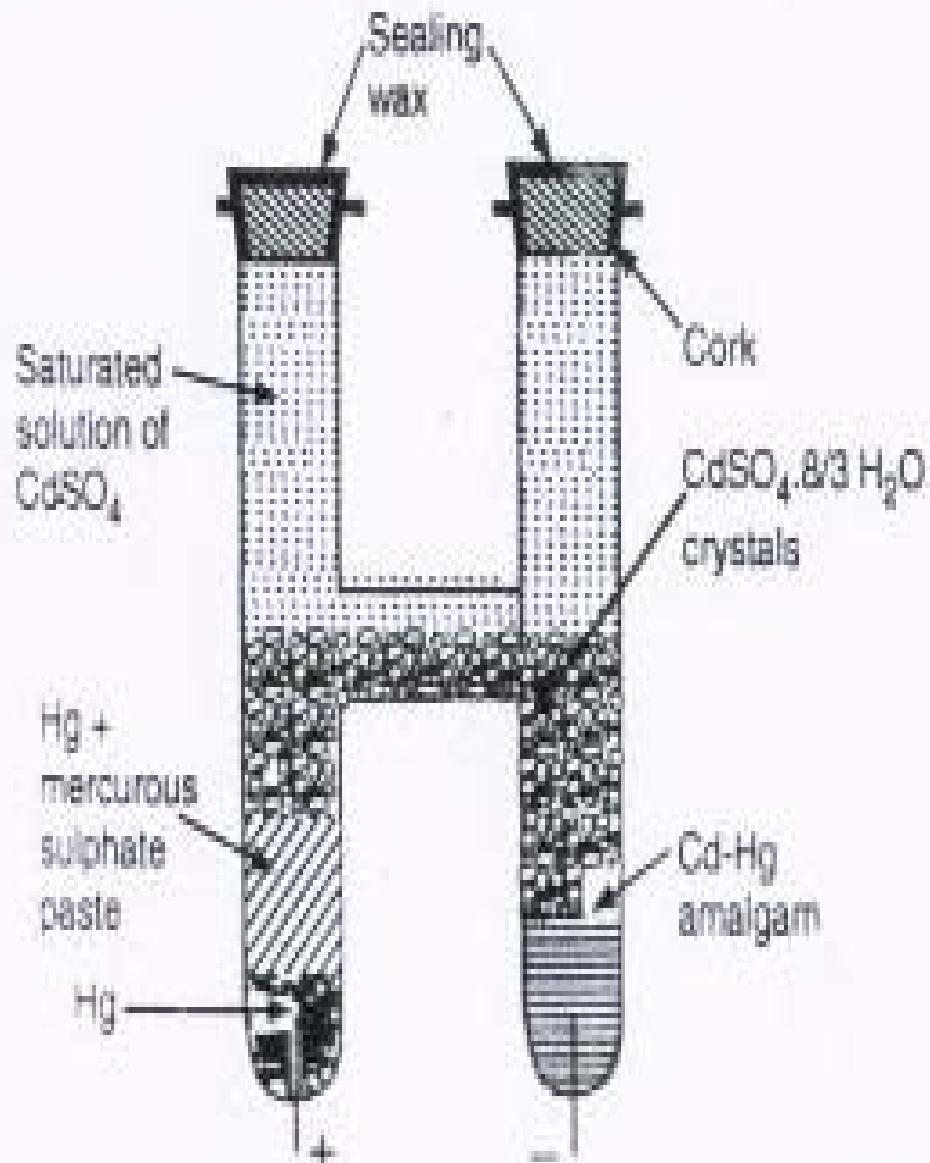
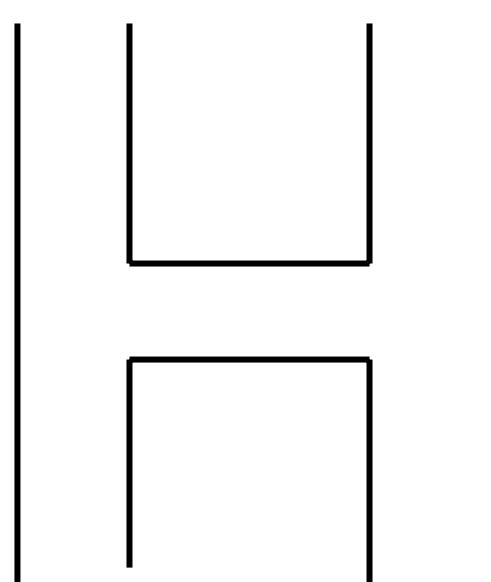


Fig. 6. Weston standard cell

L-27 Batteries & Battery technology –

Primary cells

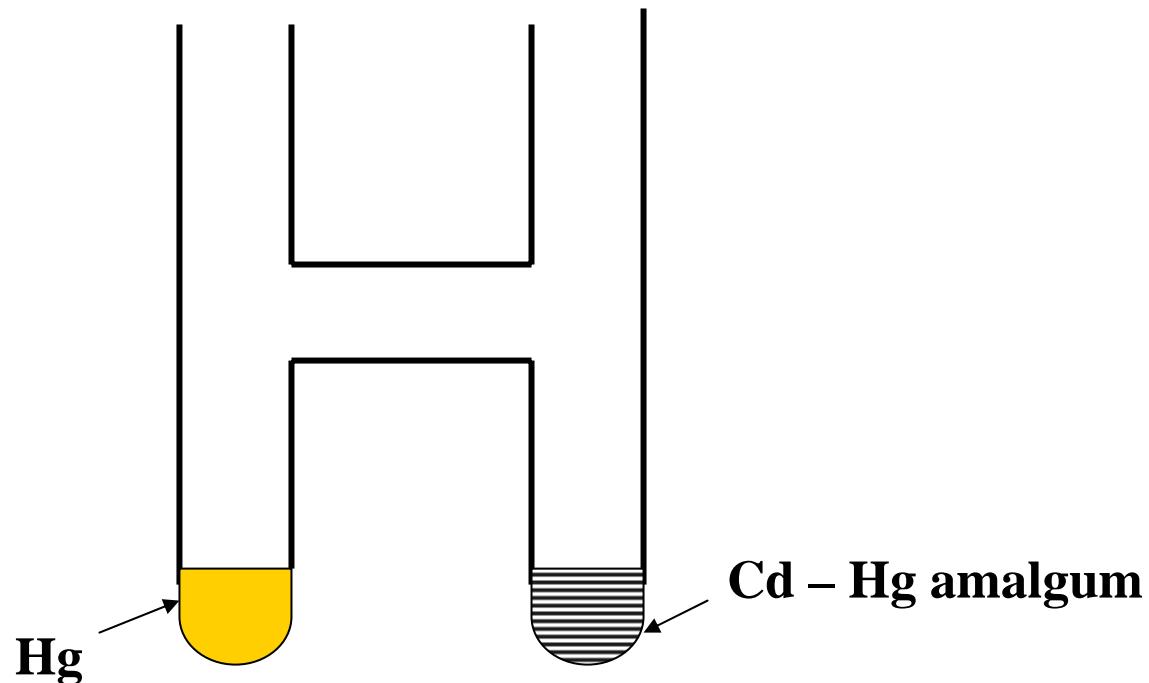
Weston Standard cadmium cell



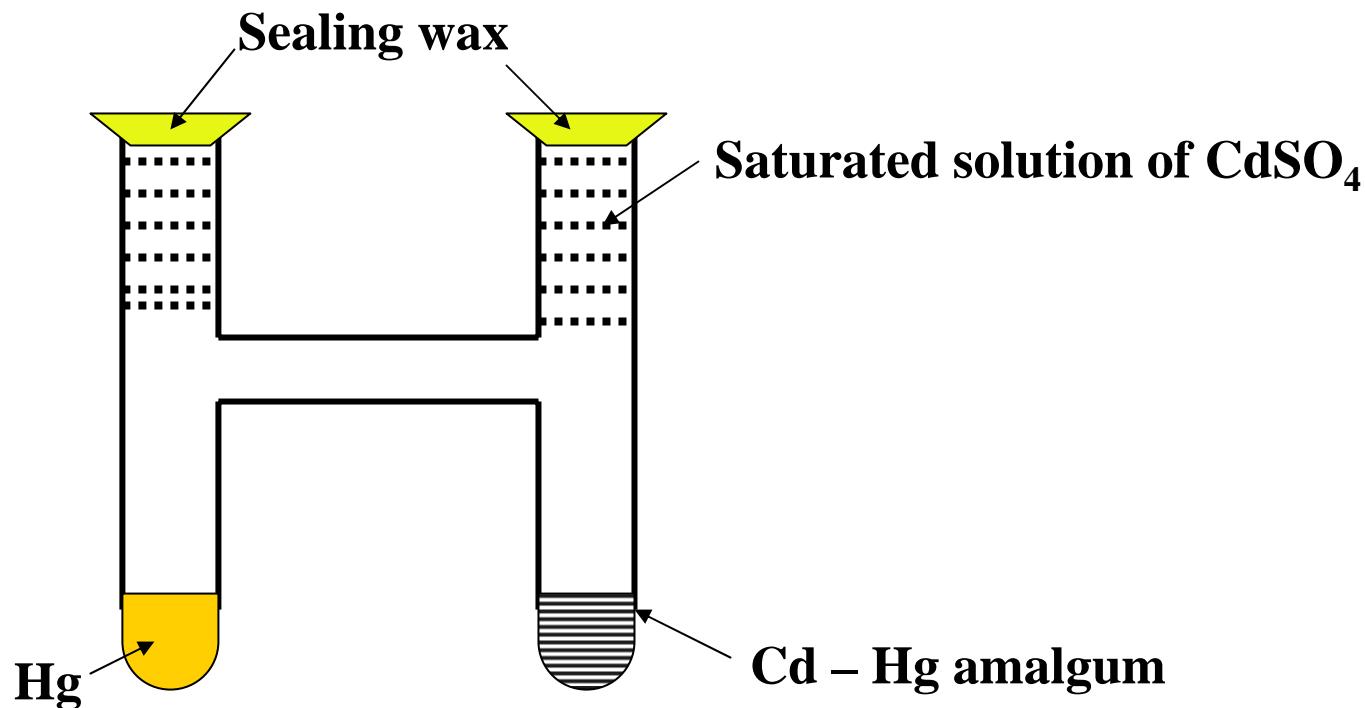
L-27 Batteries & Battery technology –

Primary cells

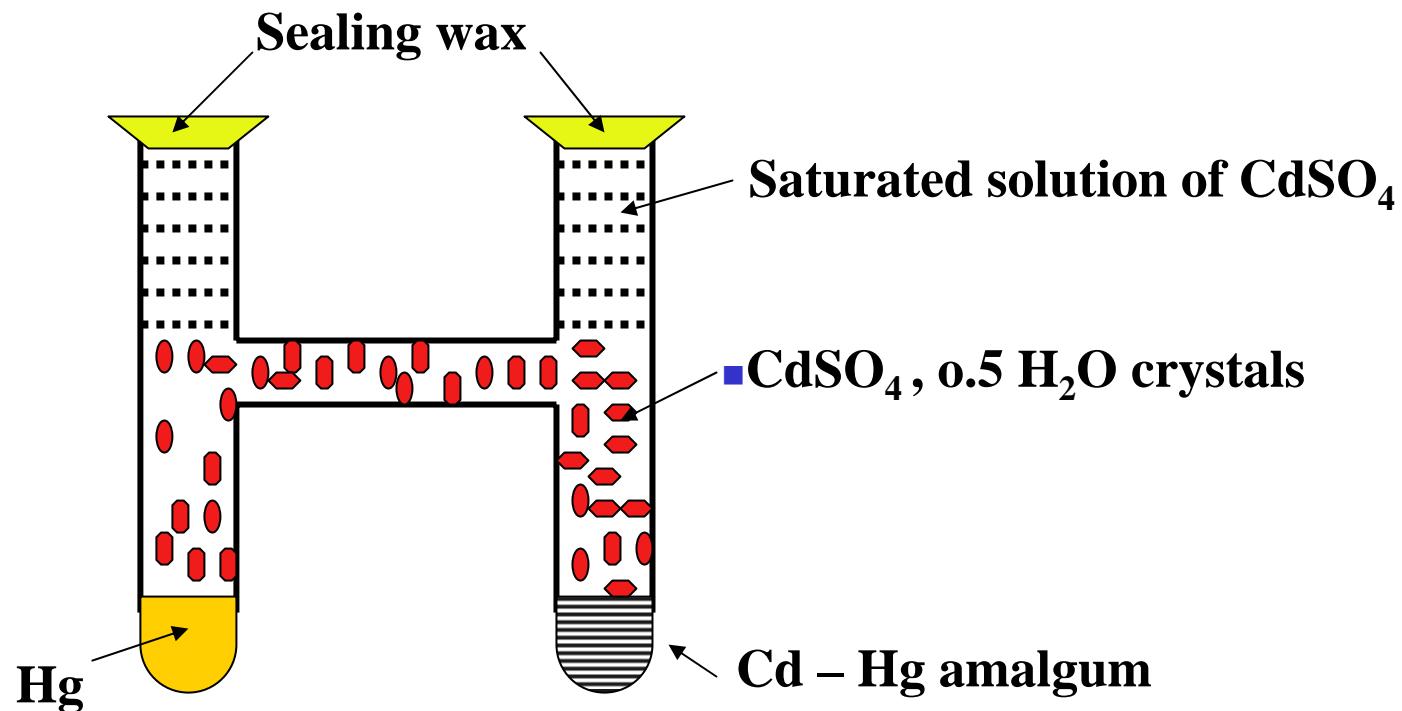
Weston Standard cadmium cell



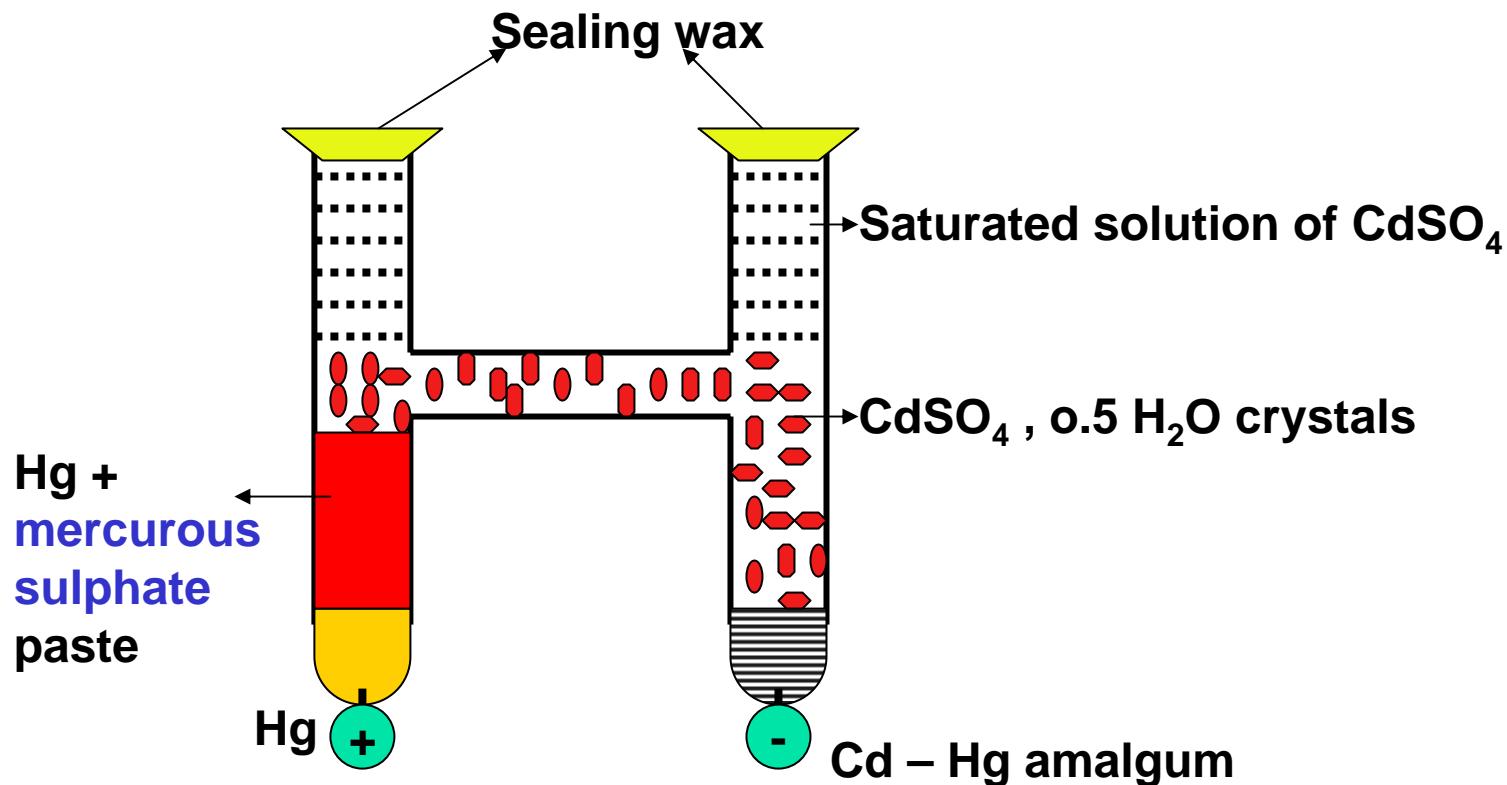
Weston Standard cadmium cell

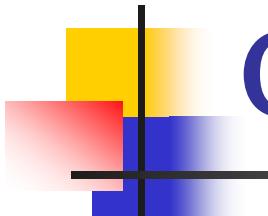


Weston Standard cadmium cell



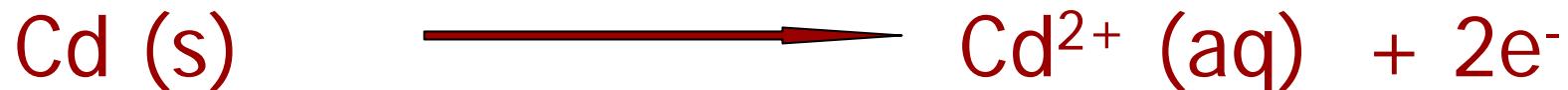
Weston Standard cadmium cell



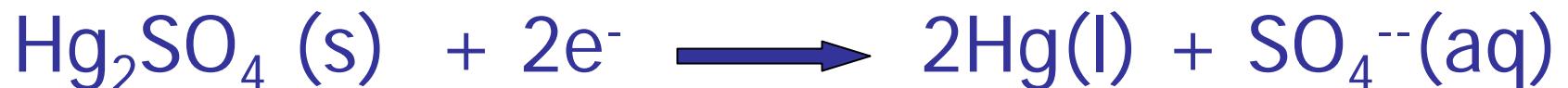


Chemical reaction

Anode (-)



Cathode (+)



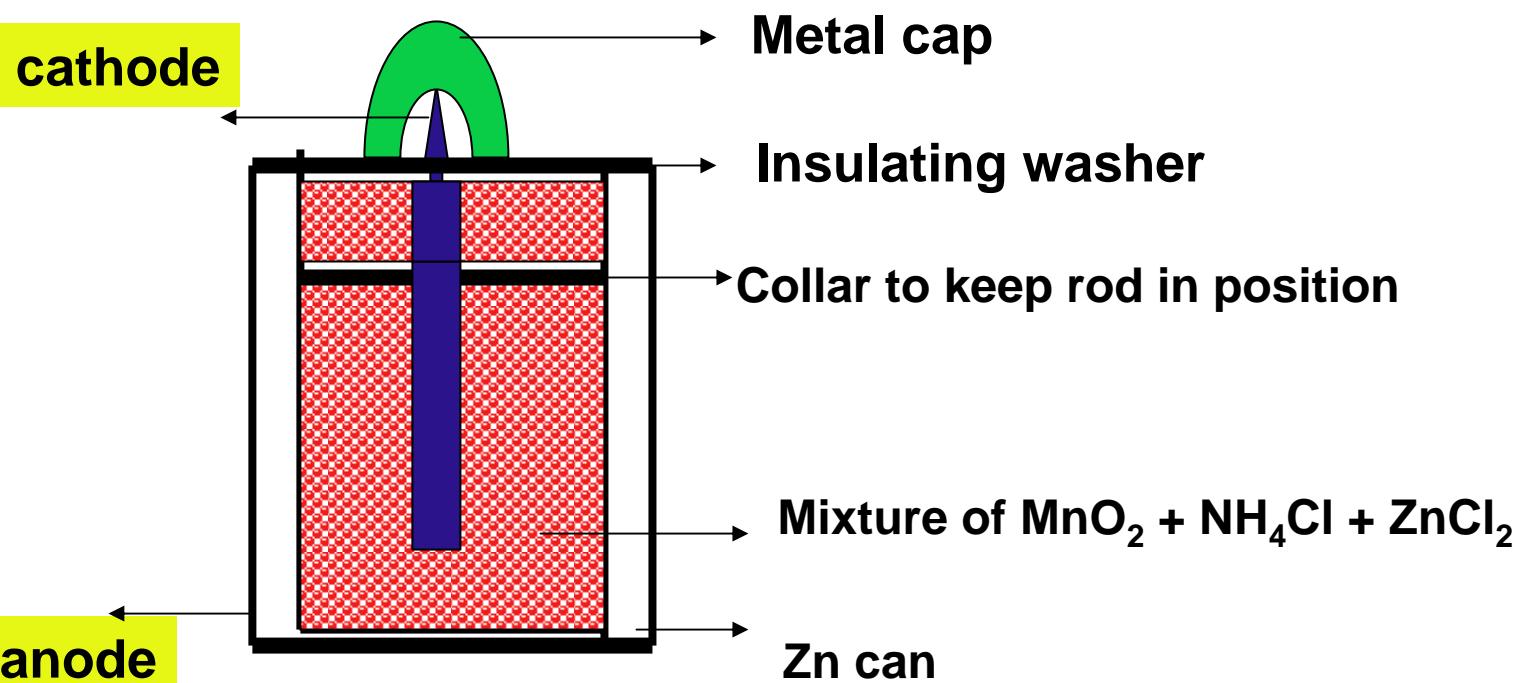
L-27 Batteries & Battery technology

Primary cells

Dry / Laclanche cell

- A cell without fluid component
- Anode – Zn can
- Cathode - carbon / graphite rod

Dry / Laclanche cell



L-27 Batteries & Battery technology

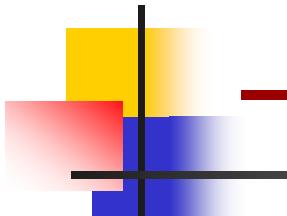
Primary cells

Chemical reaction

Anode



L-27 Batteries & Battery technology



Primary cells

uses

Flash lightning

Transistor

calculators

L-27 Batteries & Battery technology

Primary cells

Alkaline battery

- Improved form of dry cell
- Zn in powder form & mixed
- with KOH to get gel

L-27 Batteries & Battery technology

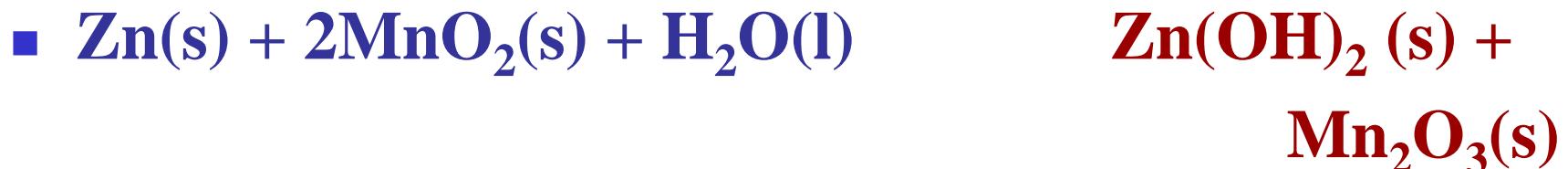
Primary cells

Chemical reaction

Anode



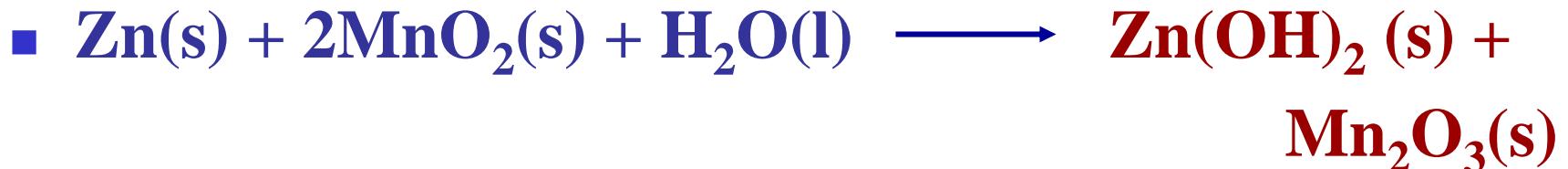
Cathode



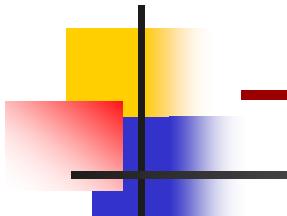
L-27 Batteries & Battery technology

Primary cells

- Over all reaction



L-27 Batteries & Battery technology



Primary cells

Mercury battery

Tiny cell

Used for specialized medicinal applications

Electrodes

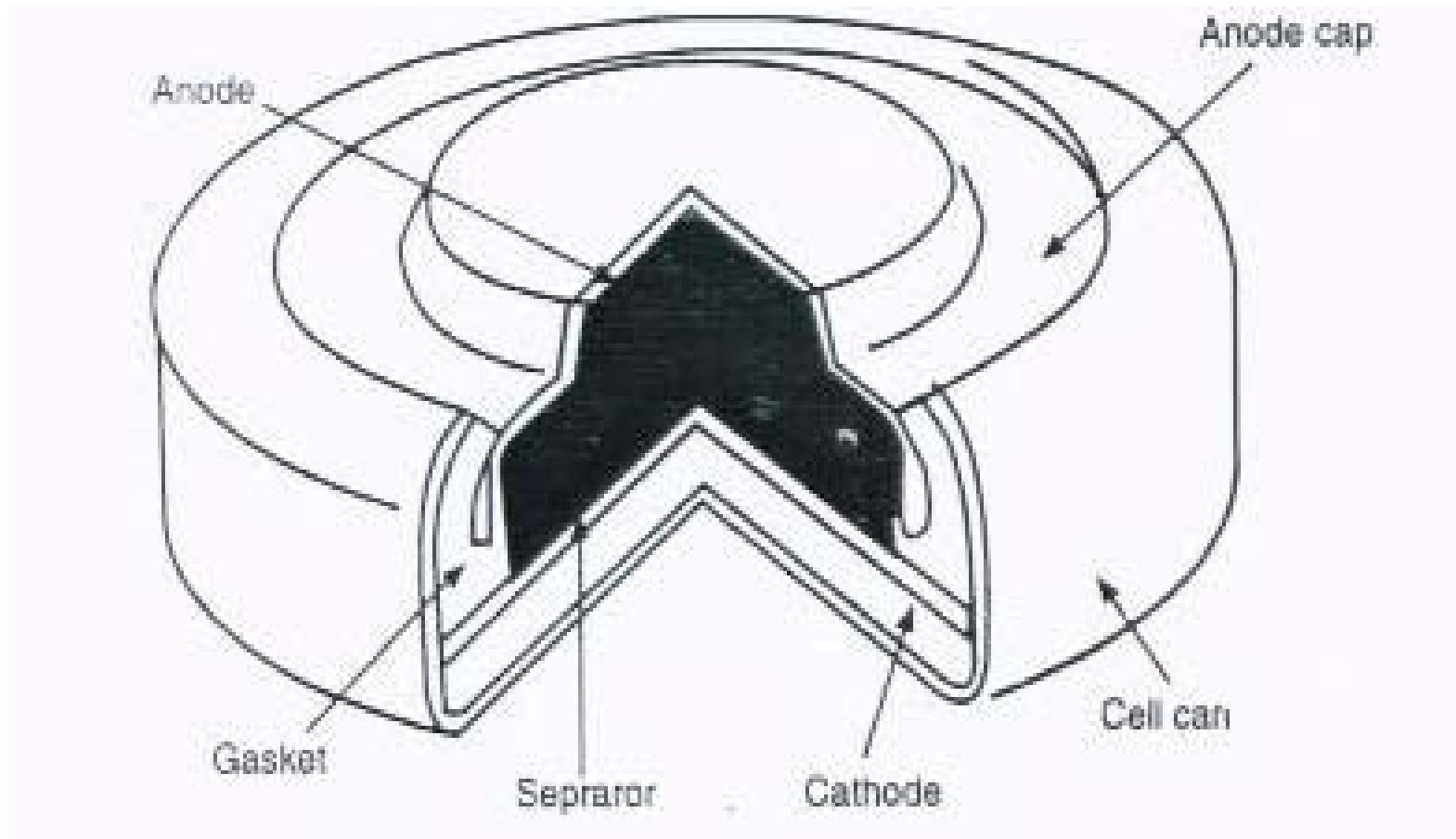
Anode – stainless steel case , Zn/Hg

Cathode _ paste , KOH, Zn(OH)_2 & HgO

L-27 Batteries & Battery technology

Primary cells

Mercury battery



L-27 Batteries & Battery technology

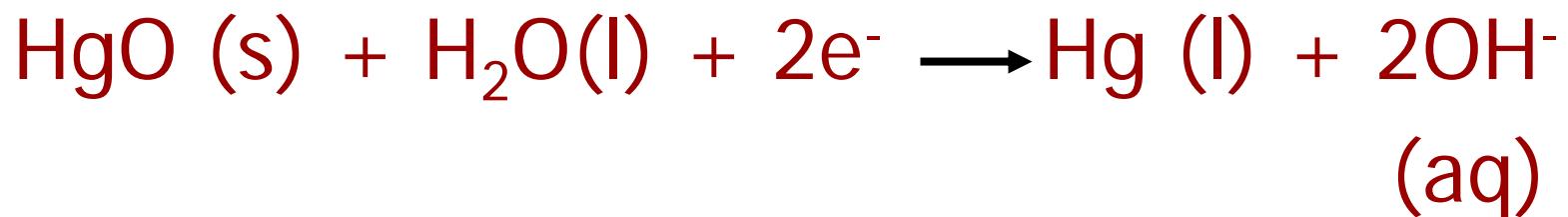
Primary cells

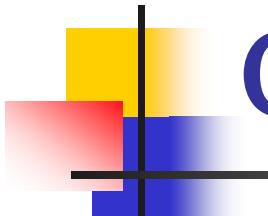
Chemical reactions

Anode

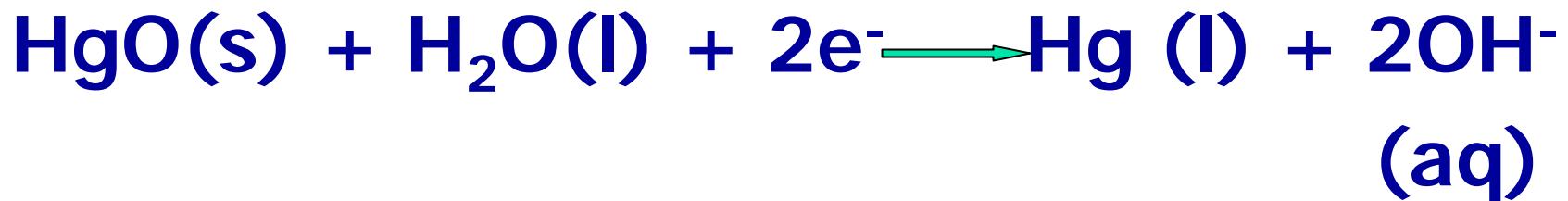
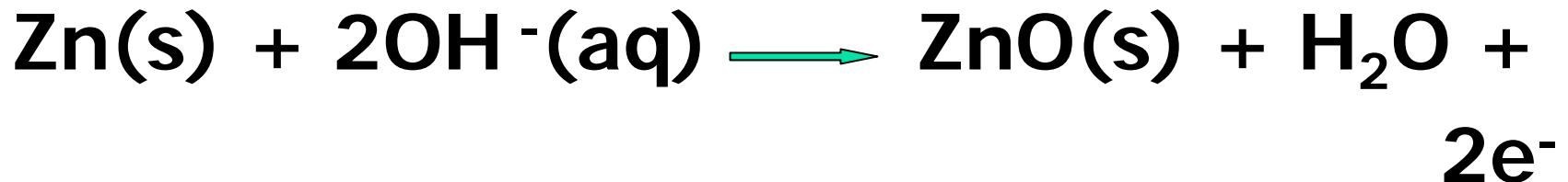


Cathode



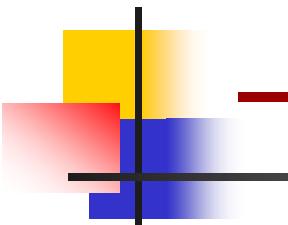


Chemical reaction

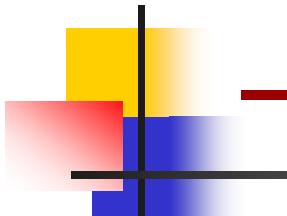


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Primary cells

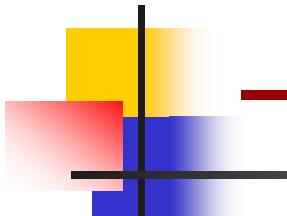


L-29 Batteries & Battery technology



secondary cells

L-29 Batteries & Battery technology



secondary cells

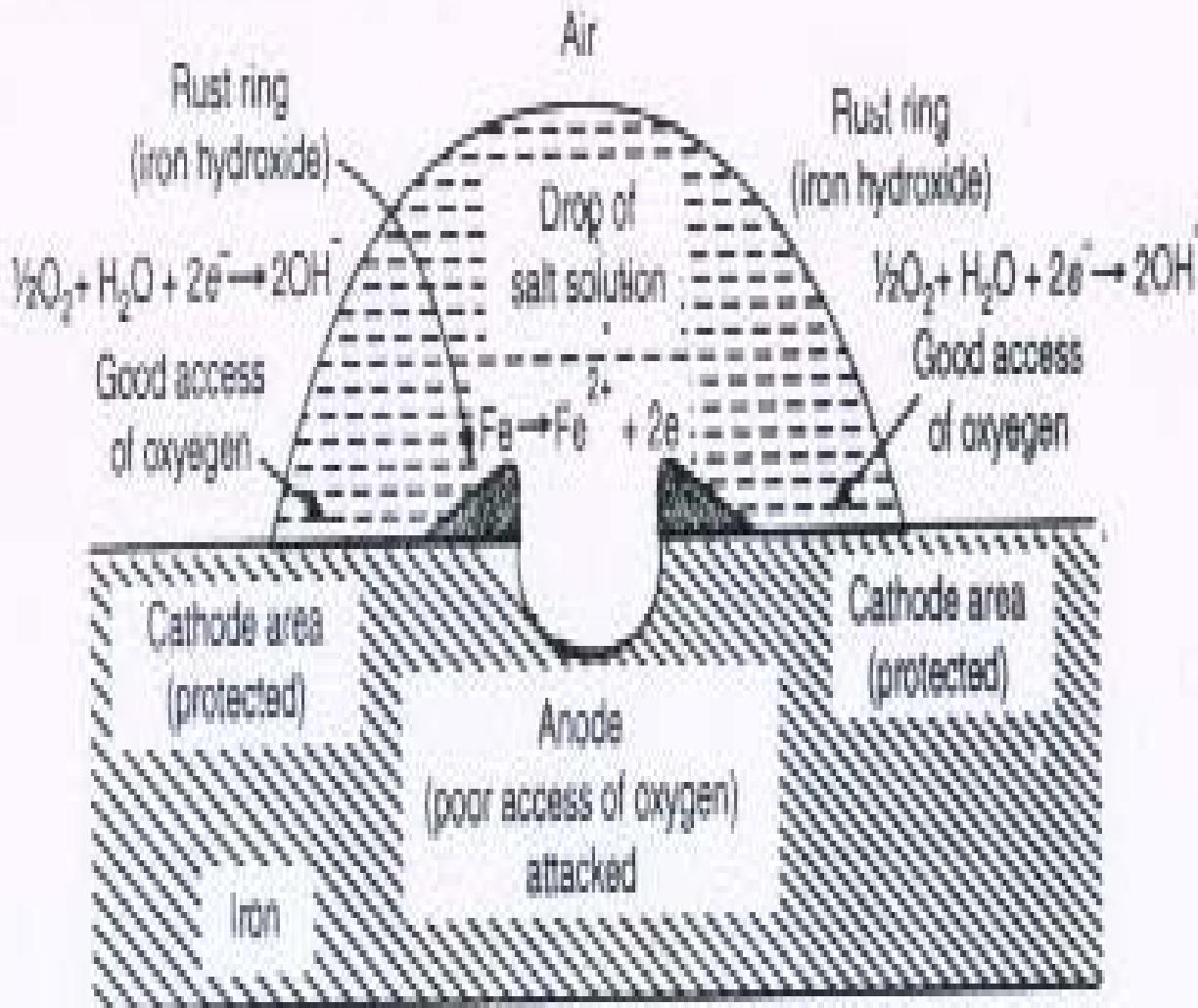


Fig. 11. Mechanism of differential aeration attack, caused by the presence of drops of salt solution on the iron surface. Metal dissolves at the less-aerated anodic areas ; whereas corrosion product (iron hydroxide) is deposited at the cathodic areas.

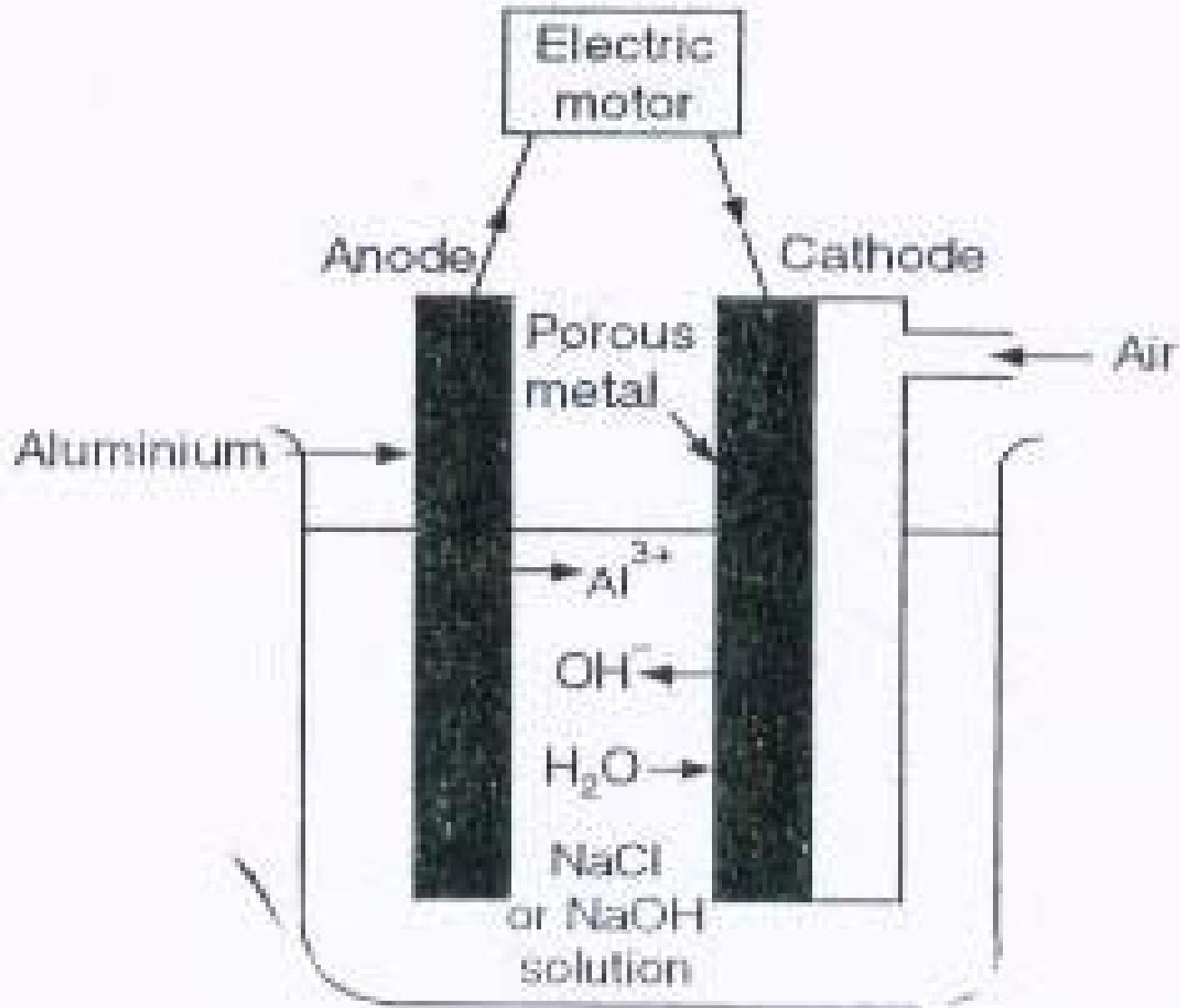


Fig. 18. An a aluminum air battery.

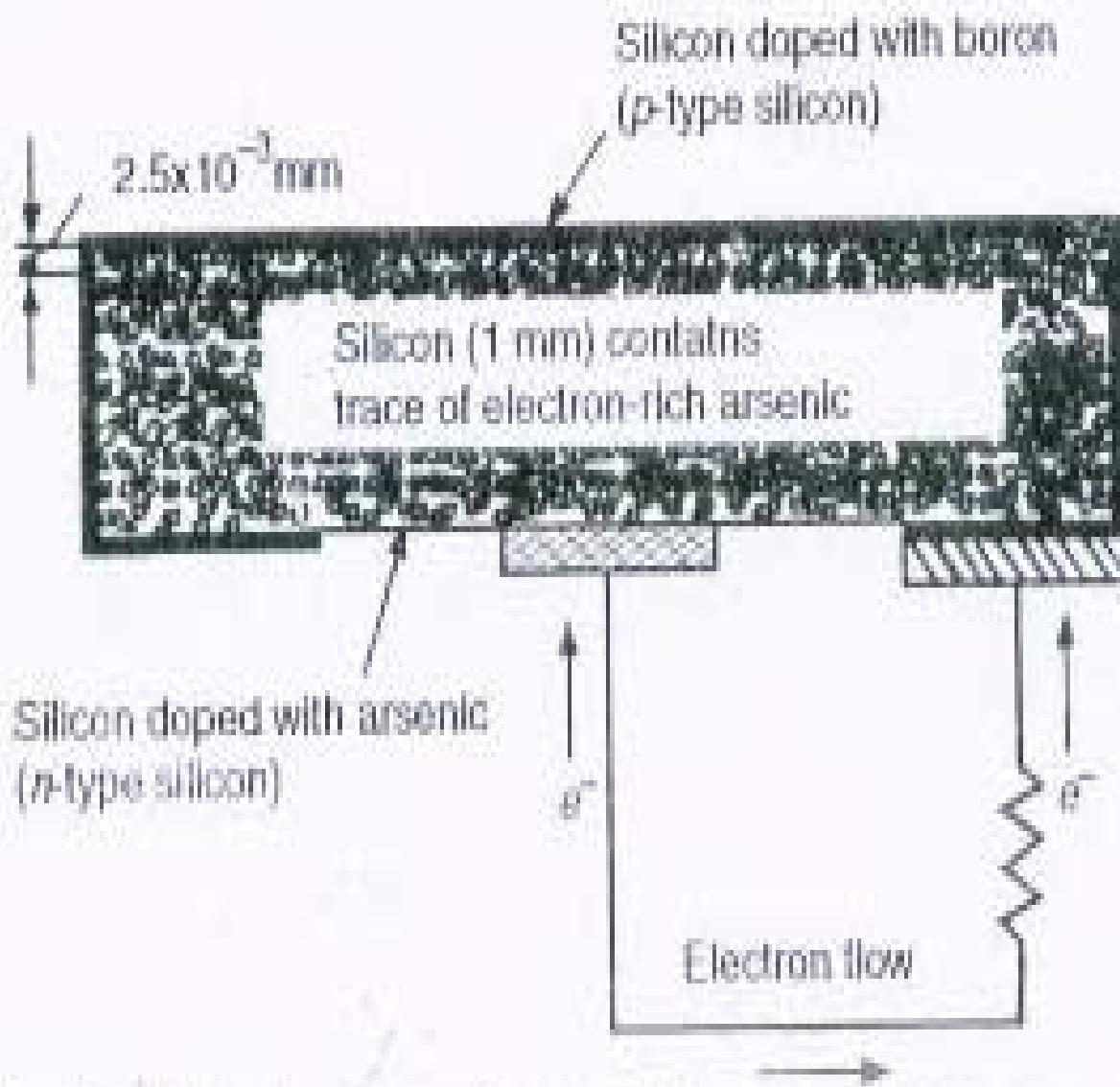
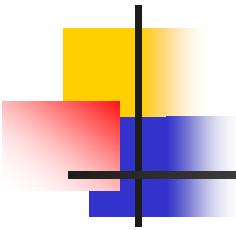


Fig. 19. A photovoltaic (solar) cell using silicon-based semiconductors.



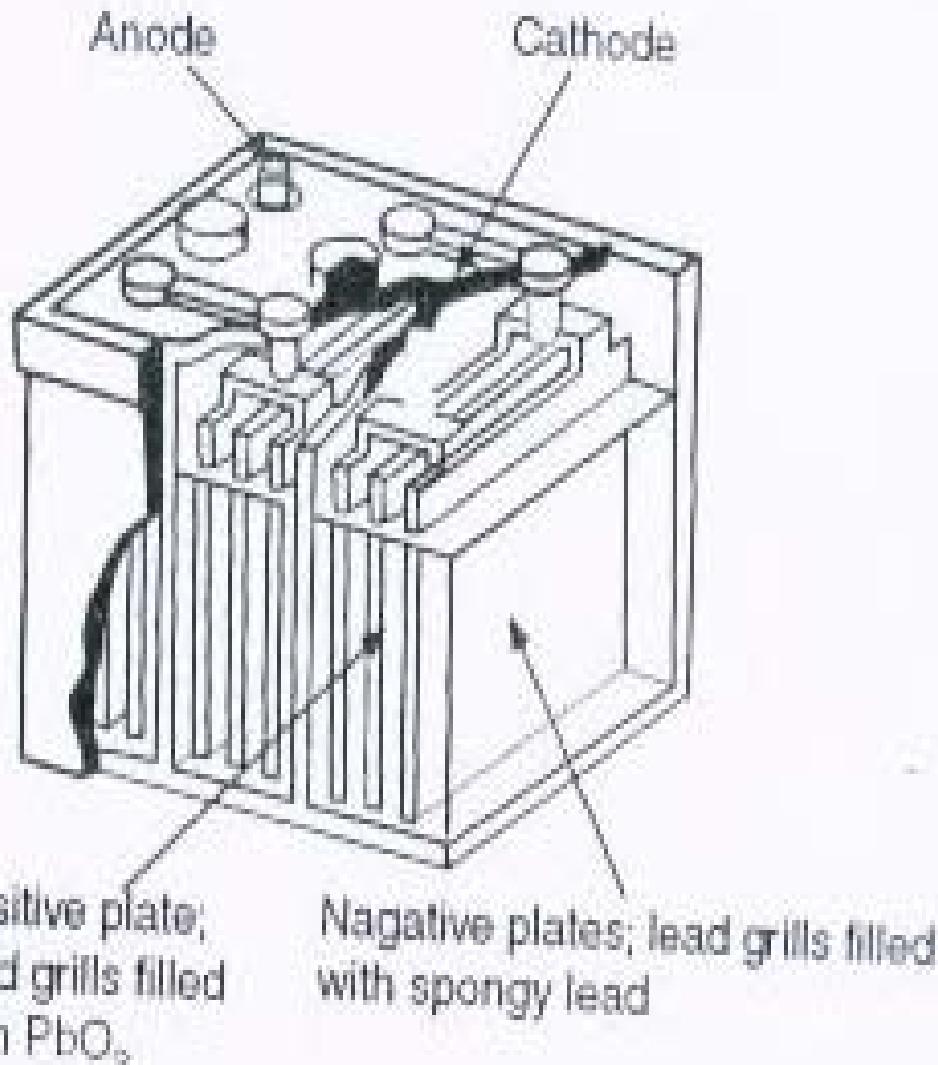


Fig. 20. A lead accumulator for car consists of six lead-acid storage cells in series and it is capable of delivering 12 V.

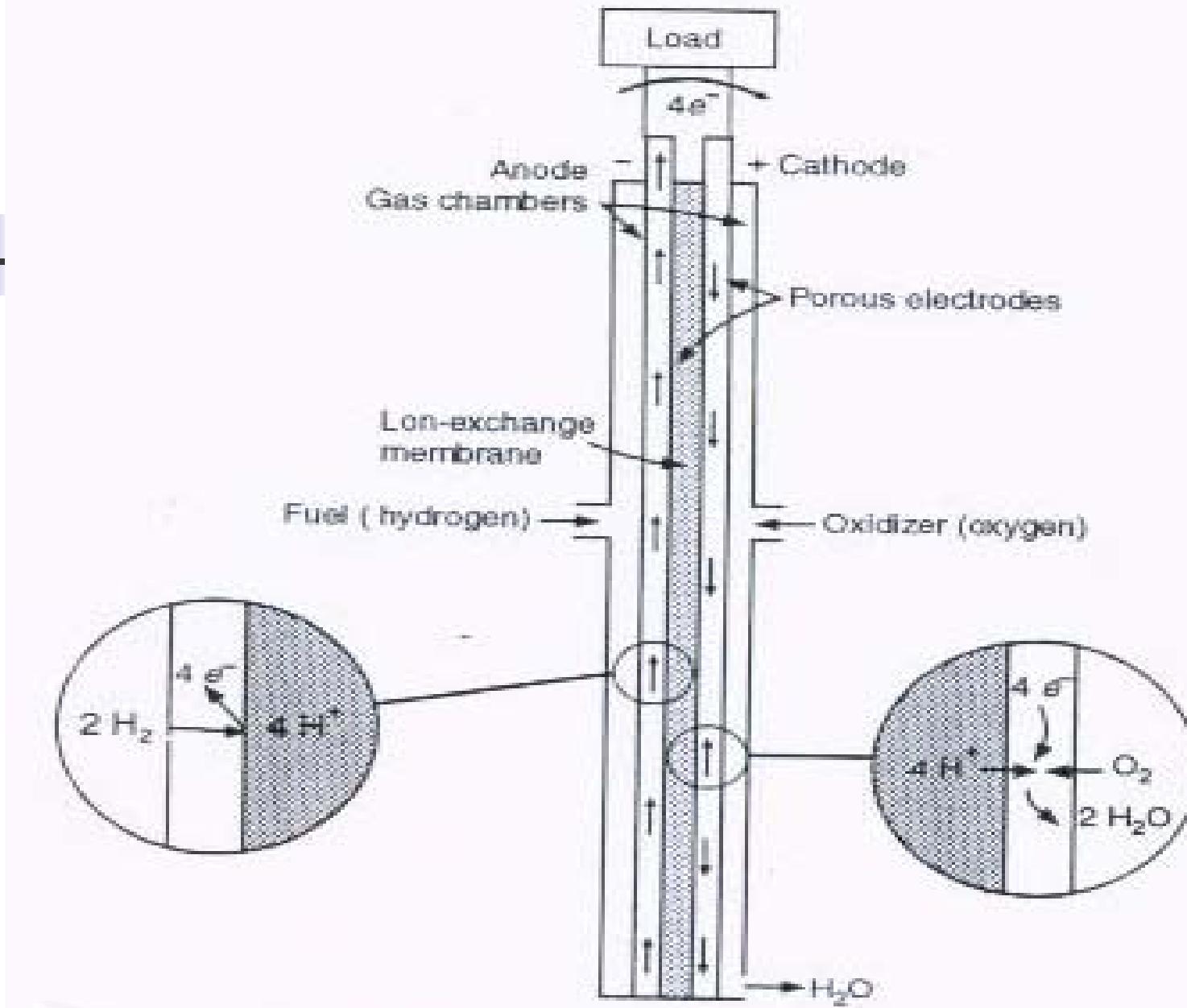


Fig. 17. Hydrogen-oxygen fuel cell.