AIRCRAFT MATERIALS AND PROCESSES

MODULE V – CORROSION

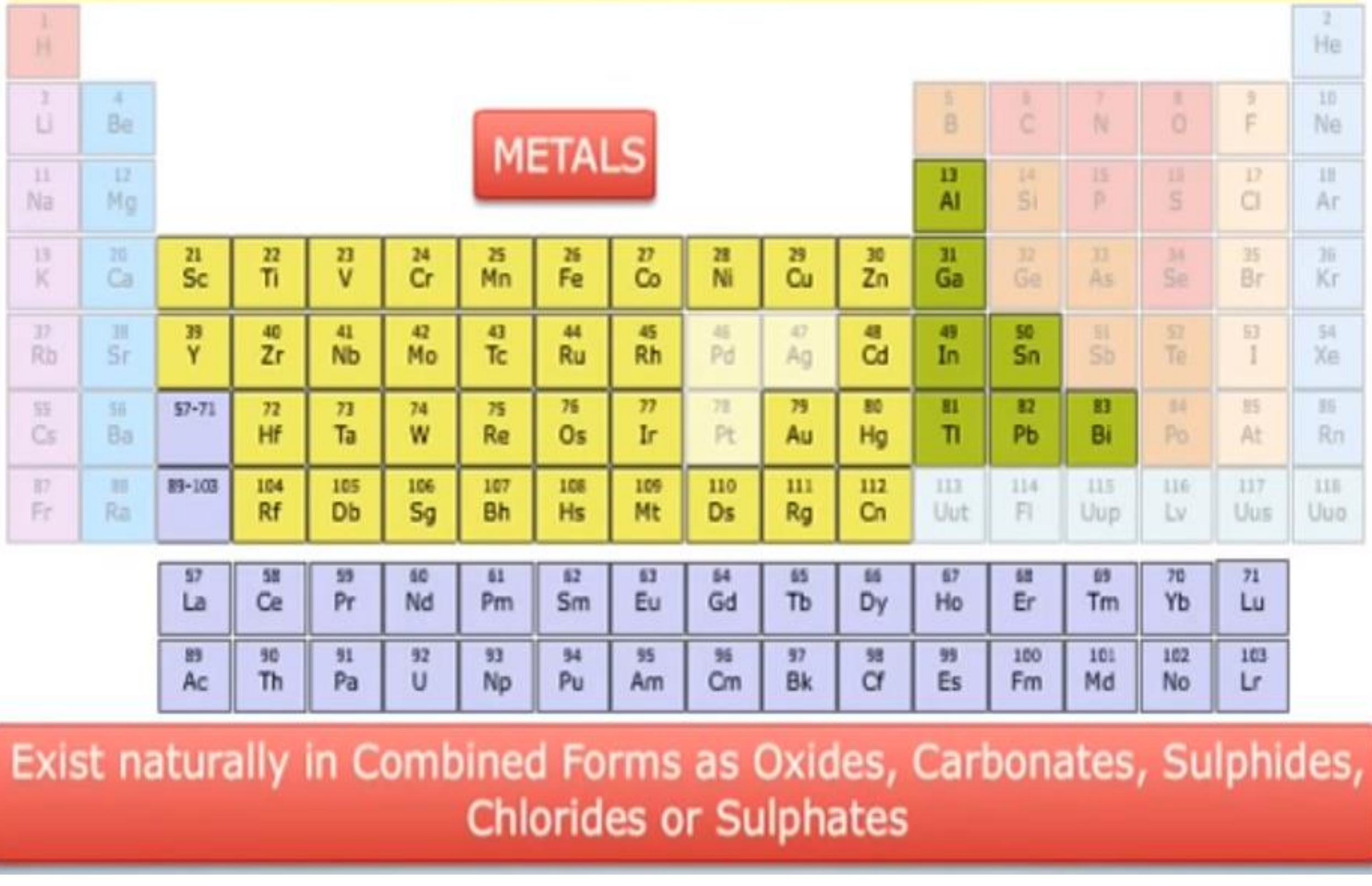
John George

Asst. Professor

Dept. of Aeronautical Engineering

Jawaharlal College of Engineering & Technology

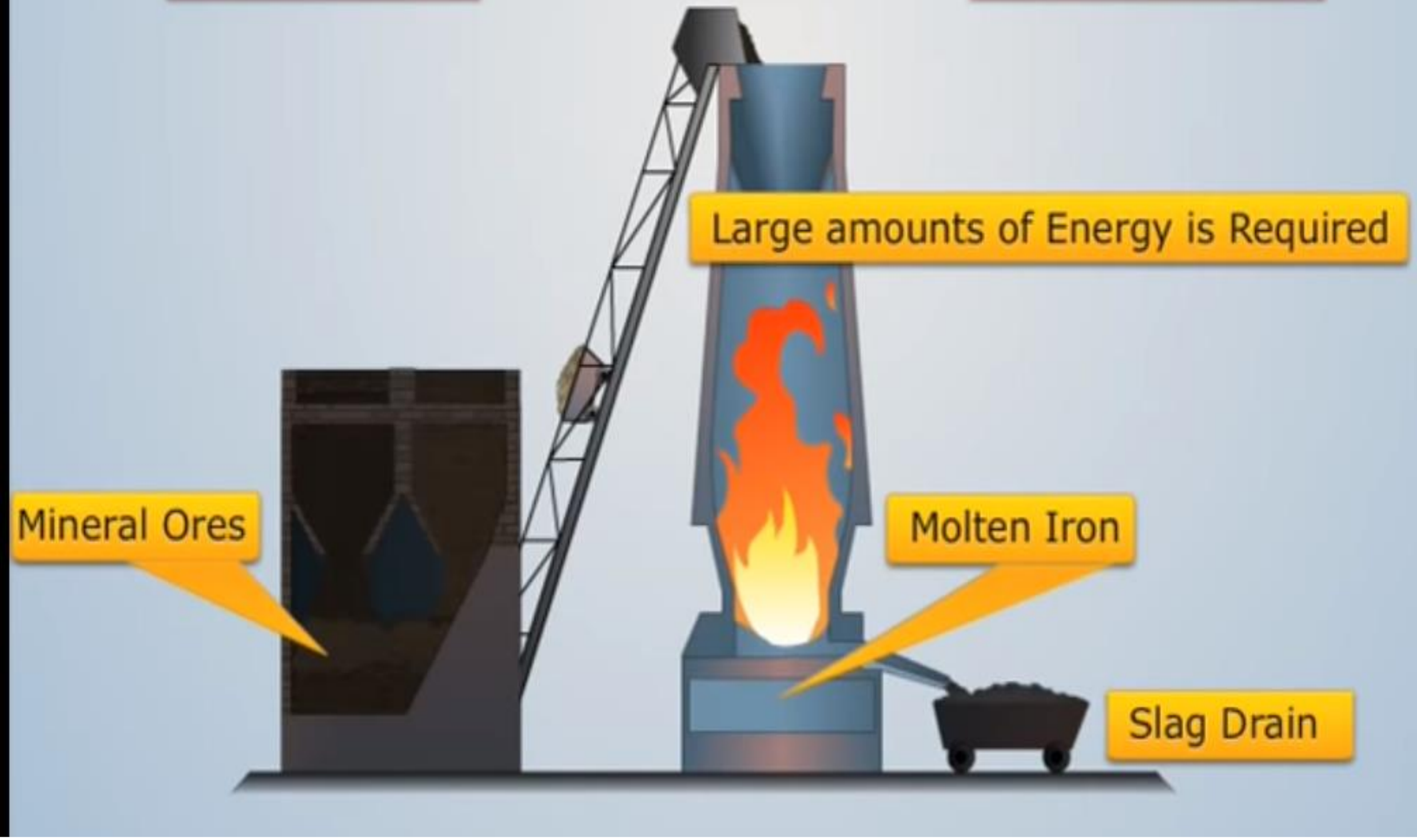
Periodic Table



Exist naturally in Combined Forms as Oxides, Carbonates, Sulphides, Chlorides or Sulphates

EXTRACTION PROCESSES

MINERAL ORES → METALLIC STATES



Lower Energy STATE

EXTRACTION PROCESSES

Higher Energy EXCITED STATE

MINERAL ORES

METALLIC STATES

Stable Natural Combined Form

Unstable Pure Form

Greater is the amount of energy required to separate the metal from its mineral

EXTRACTION PROCESSES

MINERAL ORES

METALLIC STATES

Greater will be the tendency of the metal to revert back to its natural state

What is **Corrosion** and **List its Types.**

MINERAL ORES ← CORROSION ← METALLIC STATES

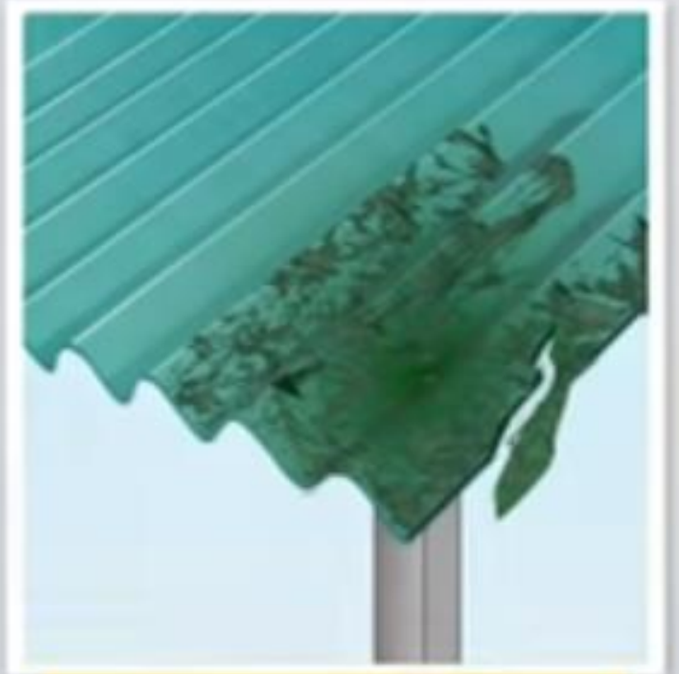
Keywords

- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

What is **Corrosion** and **List its Types.**

Metals



Polymers

Ceramics

Keywords

- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

What is **Corrosion** and **List its Types.**

- **Loss of Useful Properties due to Corrosion**
  - Weakening of metallic material due to loss of cross sectional area
  - Loss of properties such as Malleability, Ductility
  - Decaying of metal surfaces

Keywords

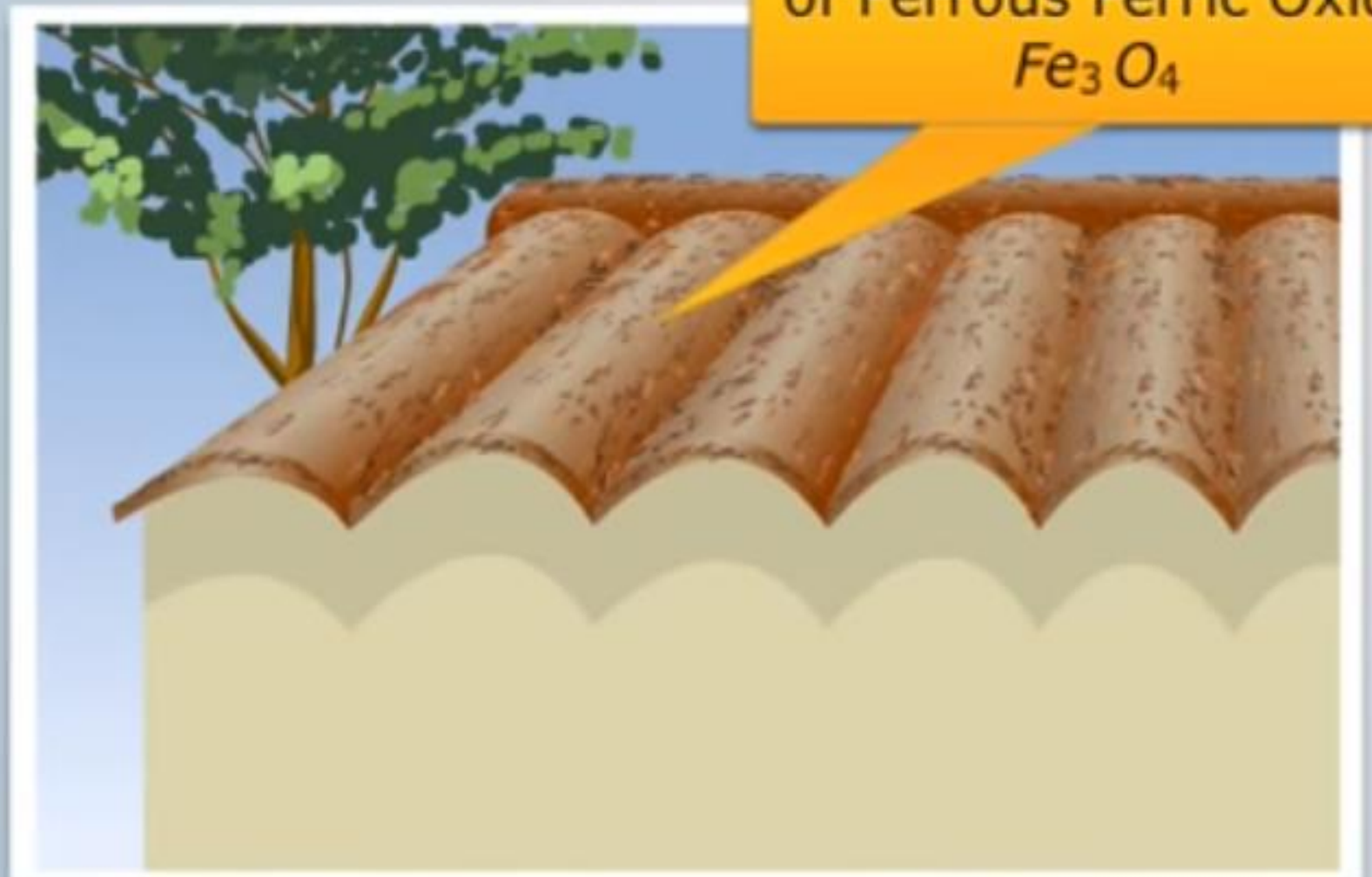
- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

What is **Corrosion** and **List its Types.**

Examples of Corrosion

- Rusting of Iron



Keywords

- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

What is **Corrosion** and **List its Types.**

Examples of Corrosion

- Rusting of Iron
- Formation of Green Film on the Surface of Copper

Keywords

- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

Green layer of basic carbonate consisting of cupric carbonate and cupric hydroxide

$$CuCO_3 + Cu(OH)_2$$

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

What is **Corrosion** and **List its Types.**

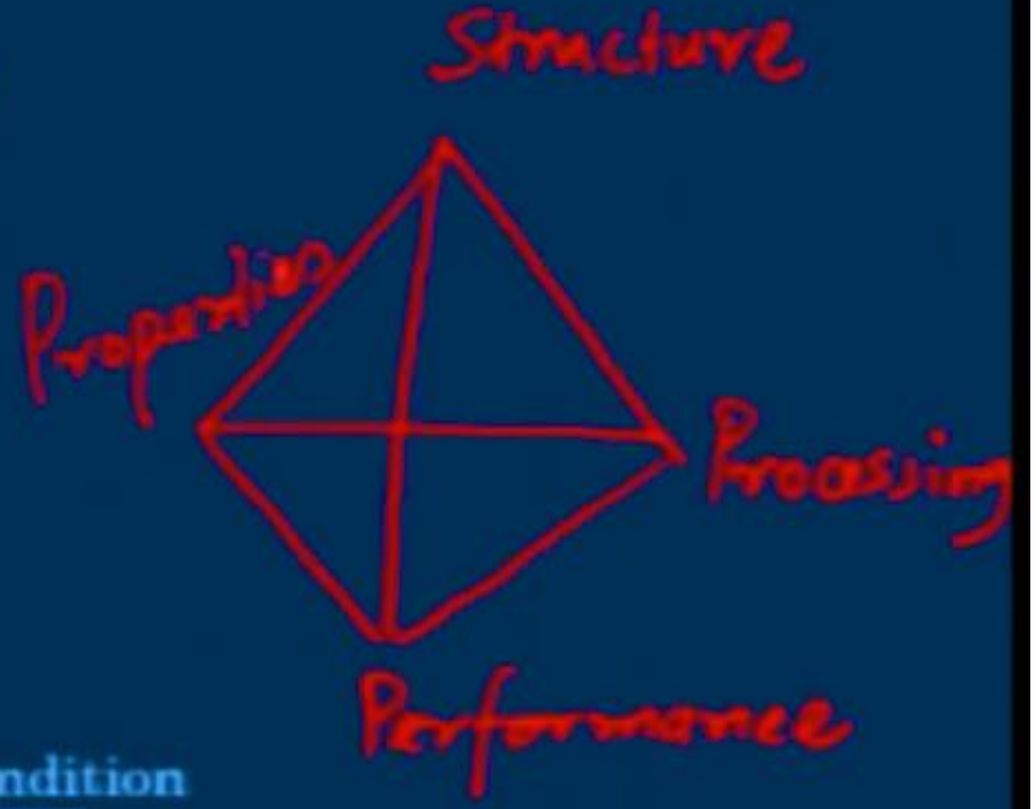
- Examples of Corrosion
  - Rusting of Iron
  - Formation of Green Film on the Surface of Copper
  - Formation of Black Coating on the Surface of Silver

Keywords

- *Deterioration*
- *Degradation*
- *Chemical*
- *Electrochemical*
- *Attack*

CORROSION is the process of *Deterioration* or *Degradation* of **Metals** through an unwanted *Chemical* or *Electrochemical Attack* by its **Environment.**

Material & Environments



Air & Gas Env.

Temperatue
Humidity
P_{O_2}

Radiation

Material
Alloying Com.
Microstructure
Stress

Surface Condition

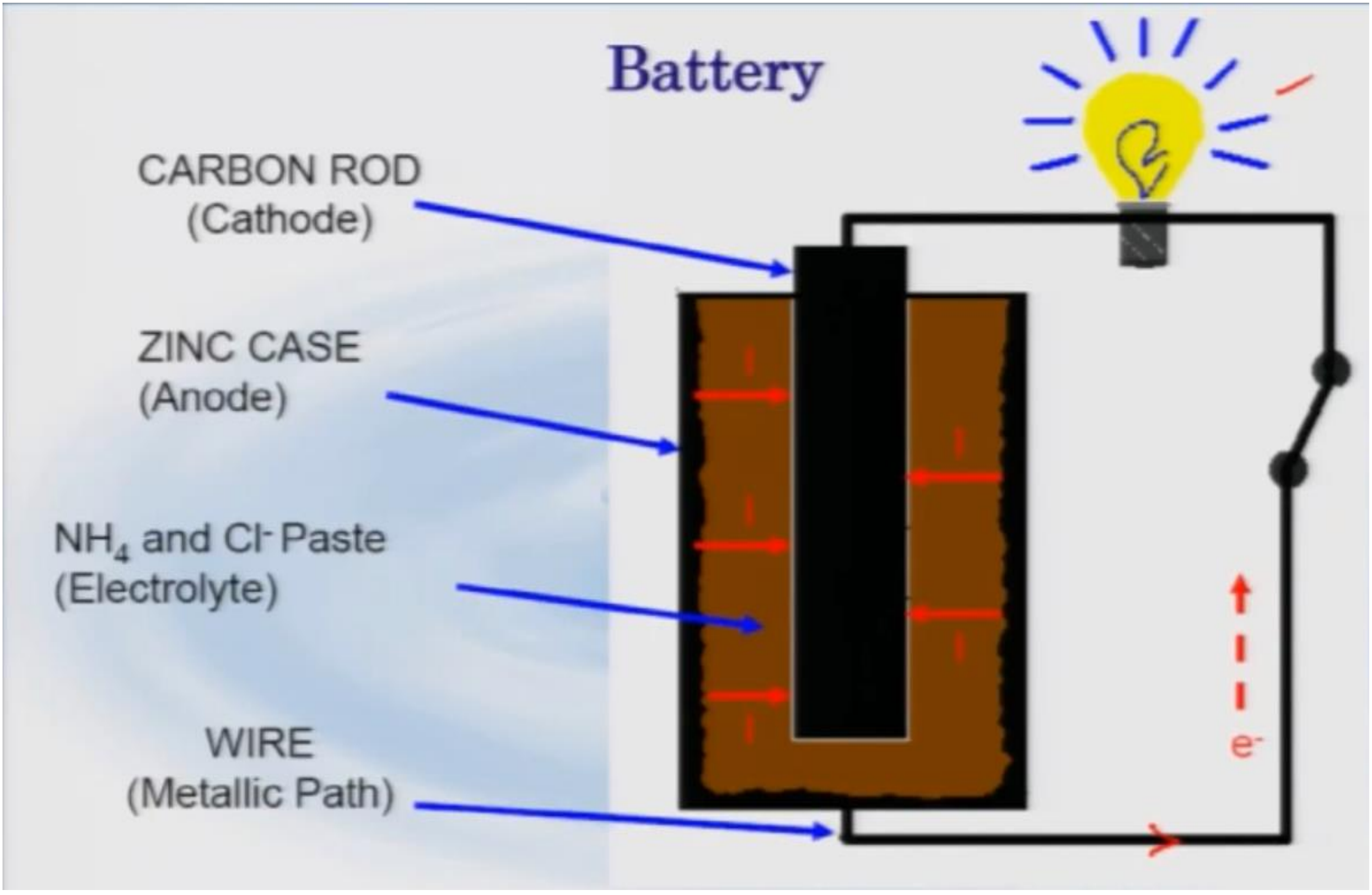
Soil

Temperature
Acidity
P_{O_2}
[Cl-]
Bacteria

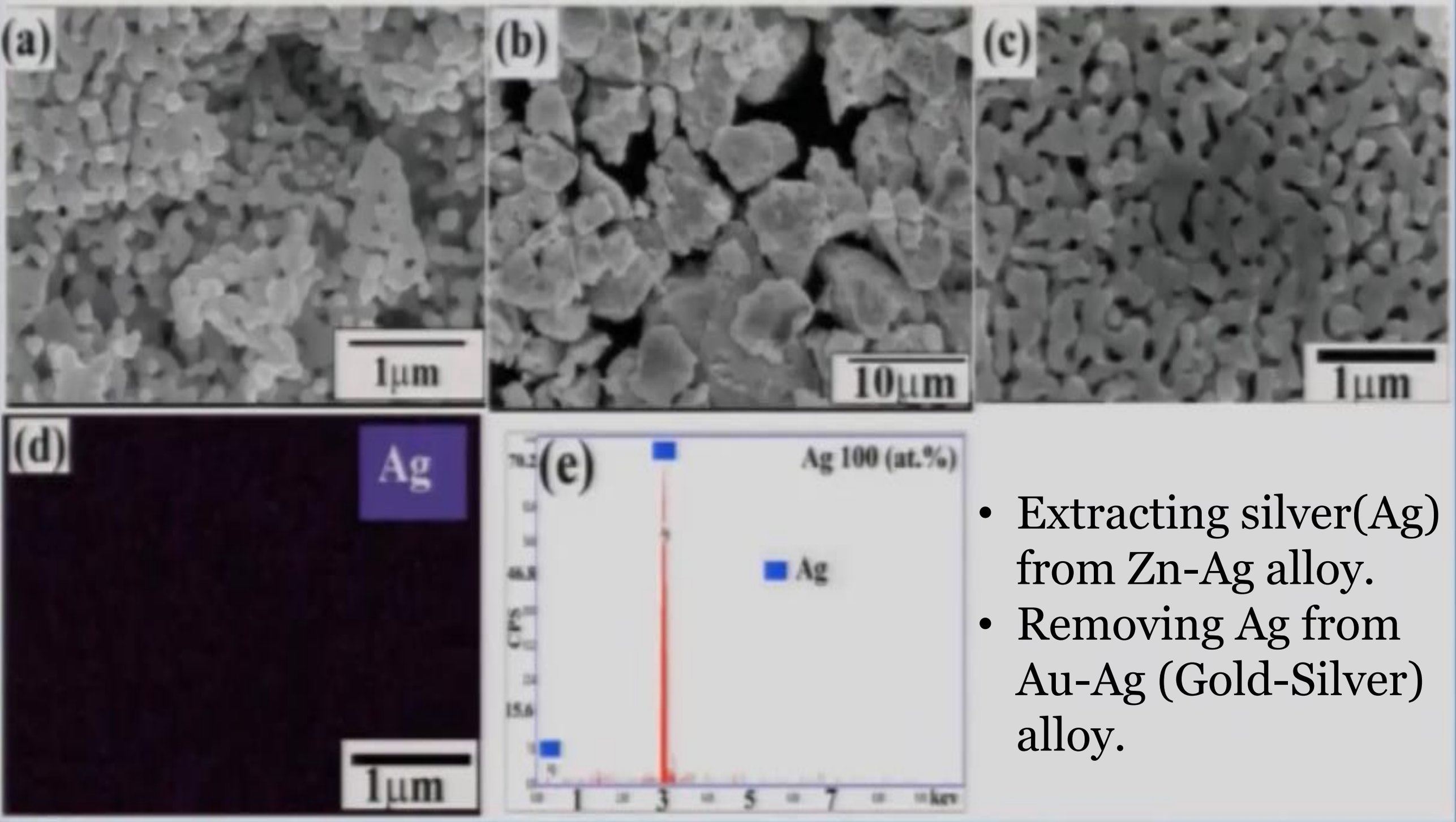
Aqueous Env.

Temperature
pH
$[O_2]$
[Cl-]
Flow velocity
Conductivity

Battery


CARBON ROD
(Cathode)
ZINC CASE
(Anode)
NH4 and Cl- Paste
(Electrolyte)
WIRE
(Metallic Path)
e-

Porous Silver by dealloying



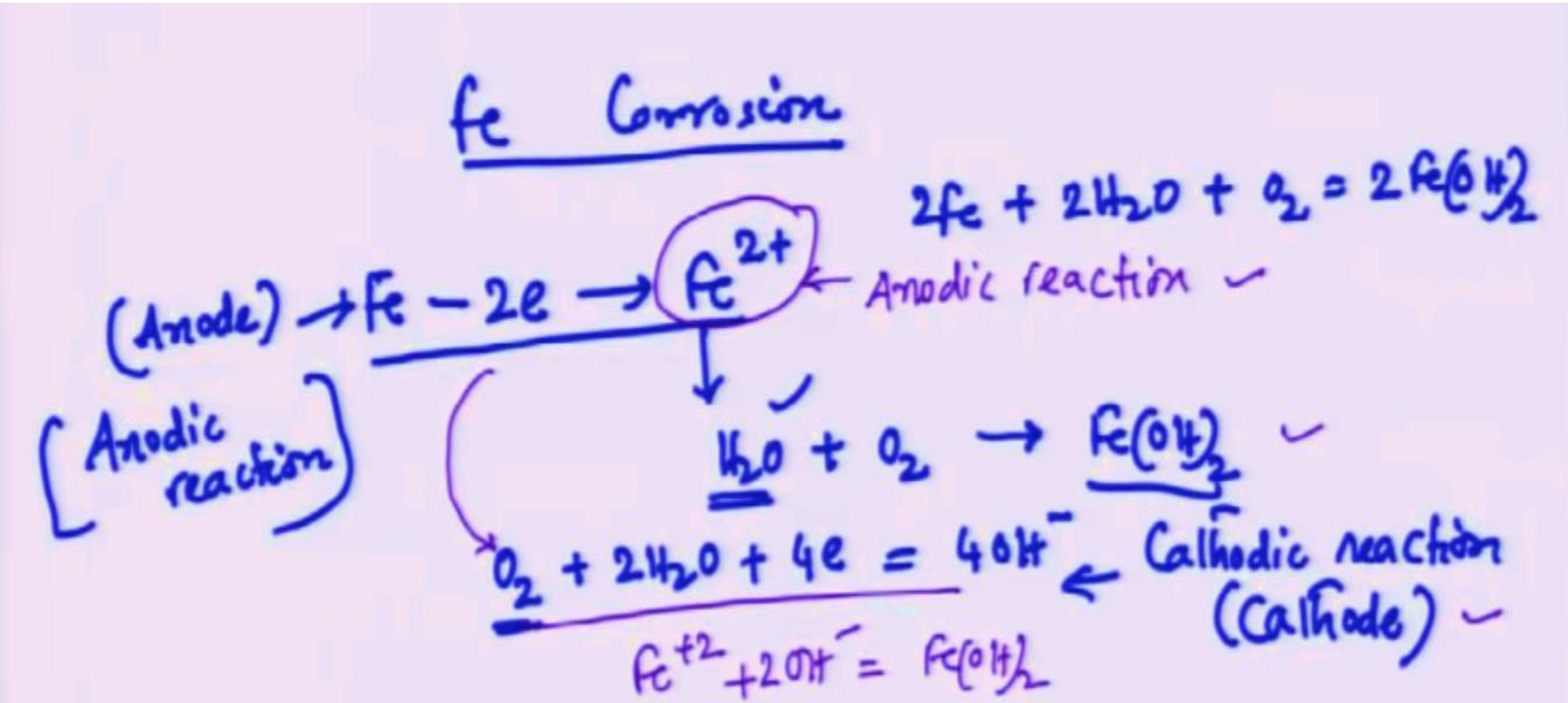
- Extracting silver(Ag) from Zn-Ag alloy.
- Removing Ag from Au-Ag (Gold-Silver) alloy.

Galvanic Zinc Applications

Zinc Metallizing

Zinc-rich Paints

Corrosion of Iron



Corrosion

Wet → H_2O (Aqueous Corrosion)

Dry (Oxidation of metal)

$$M + \frac{1}{2}O_2 = MO$$

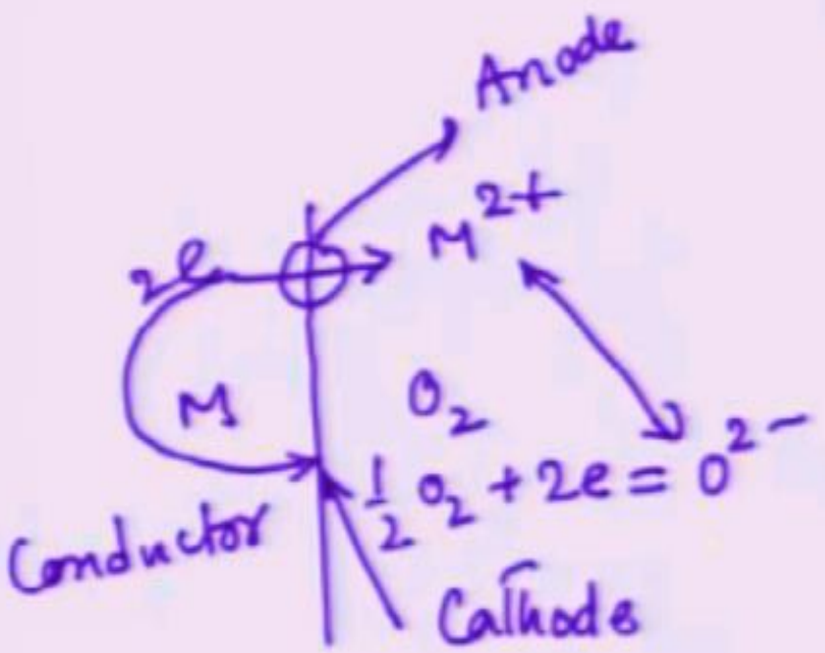
(Oxidation)
(Anodic reaction) $M - 2e \rightarrow M^{2+}$

$\frac{1}{2}O_2 + 2e \rightarrow O^{2-}$

$M + \frac{1}{2}O_2 \rightarrow M^{2+}O^{2-}$

$\rightarrow MO$

Reduction
or
Cathodic reaction



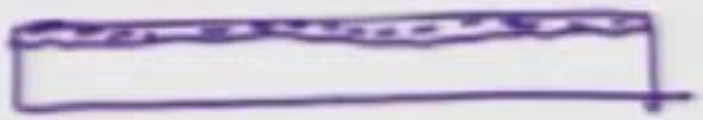
M | MO | O_2

Forms of Corrosion

1. Uniform Corrosion
2. Galvanic Corrosion
3. Crevice Corrosion
4. Pitting Corrosion
5. Dealloying / Dezincification
6. Intergranular Corrosion
7. Erosion-Corrosion
   - Fretting
   - Cavitation
8. Stress assisted Corrosion
   - Stress Corrosion
     - Corrosion fatigue
   - Hydrogen Embrittlement

Uniform Corrosion

We can easily calculate life



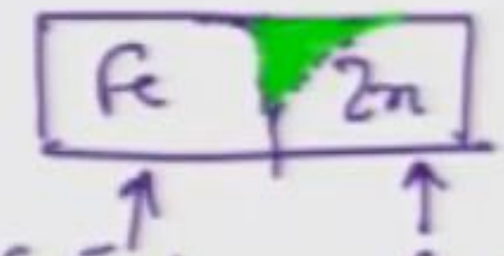
(x)

- = Coating
- = Painting
- = Cathodic protection

Galvanic Corrosion

Fe | Zn

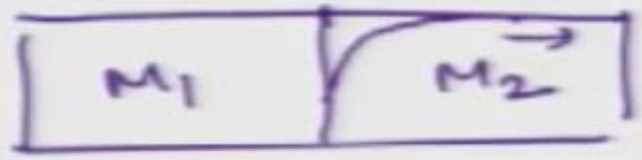
Two metal corrosion



Factors effecting Galvanic Corrosion

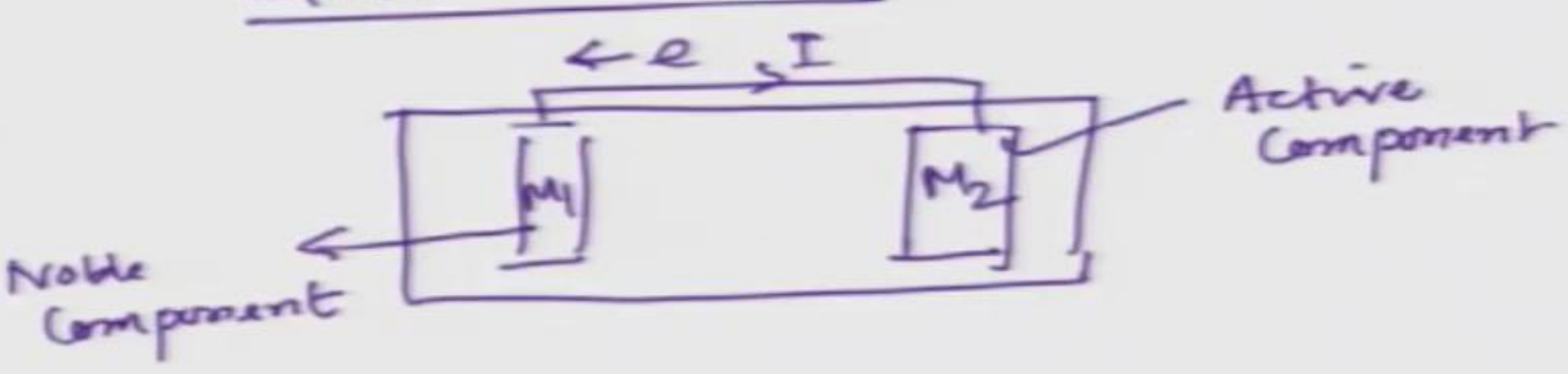
1) Distance effect

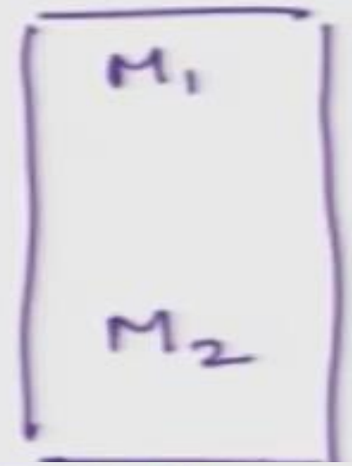
2) Polarity change

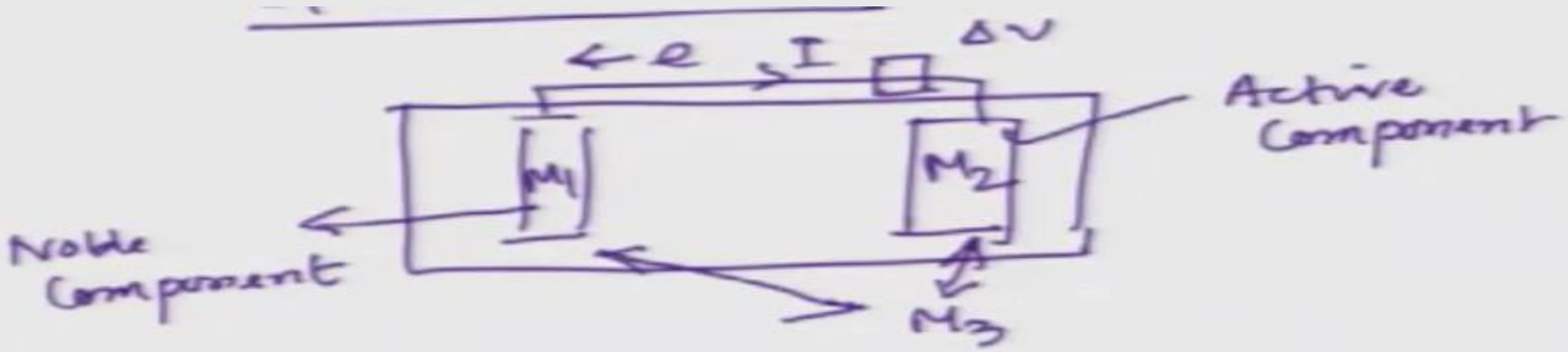


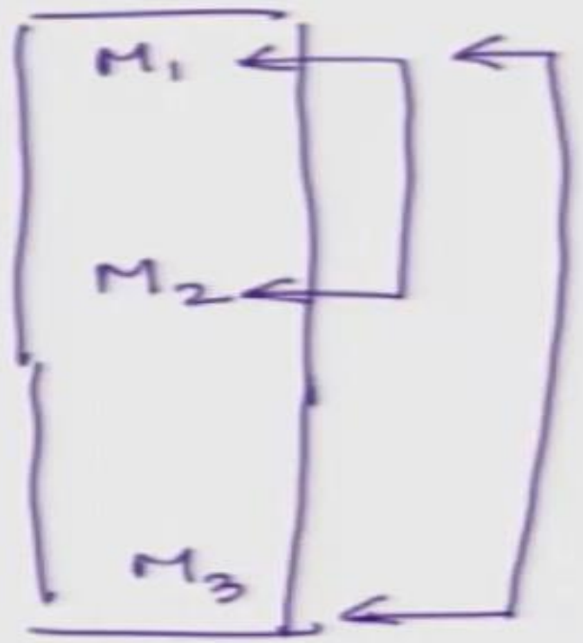
M2 active
M1 noble

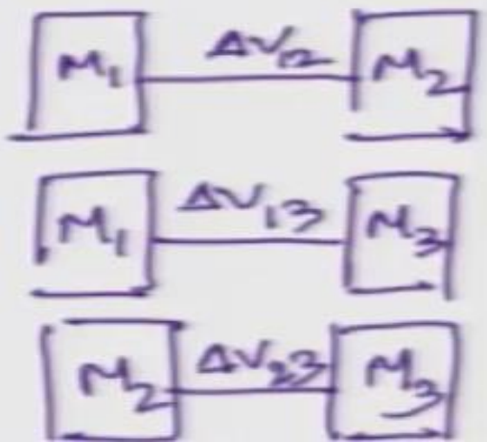
Galvanic series





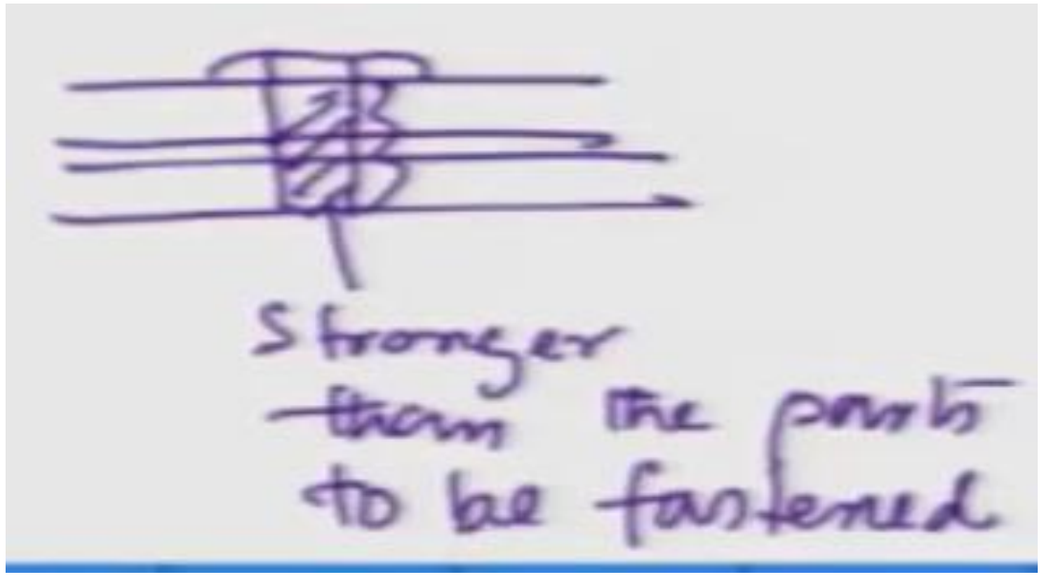


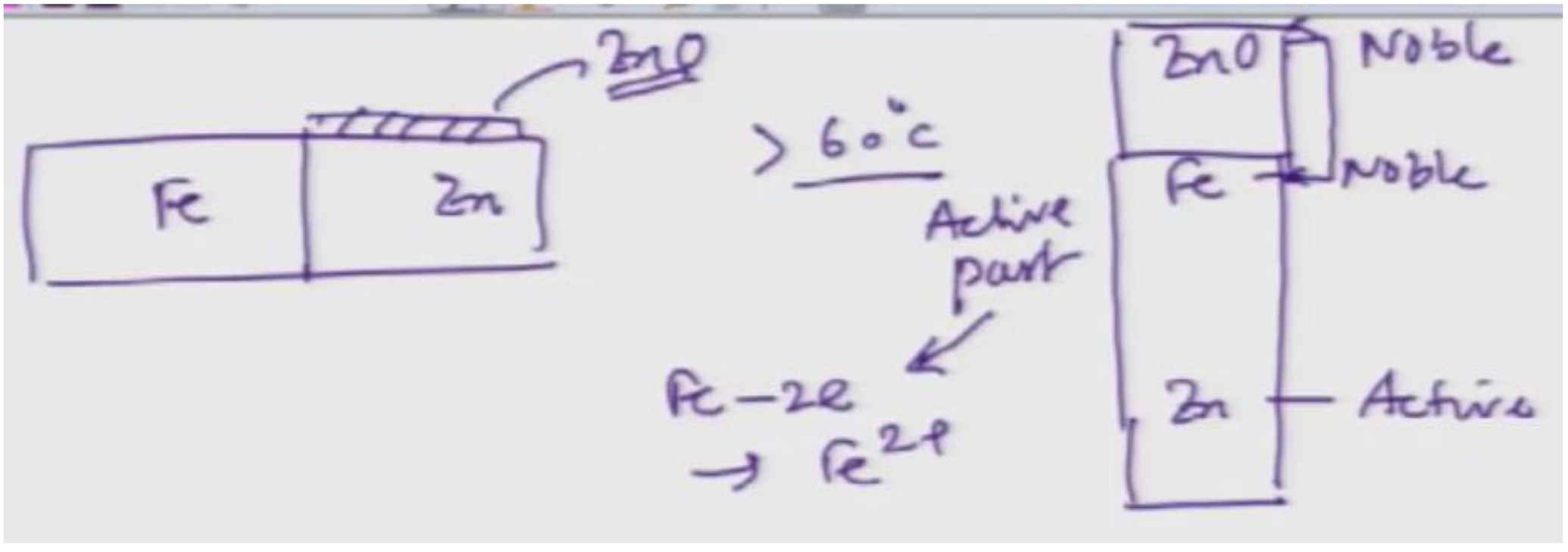




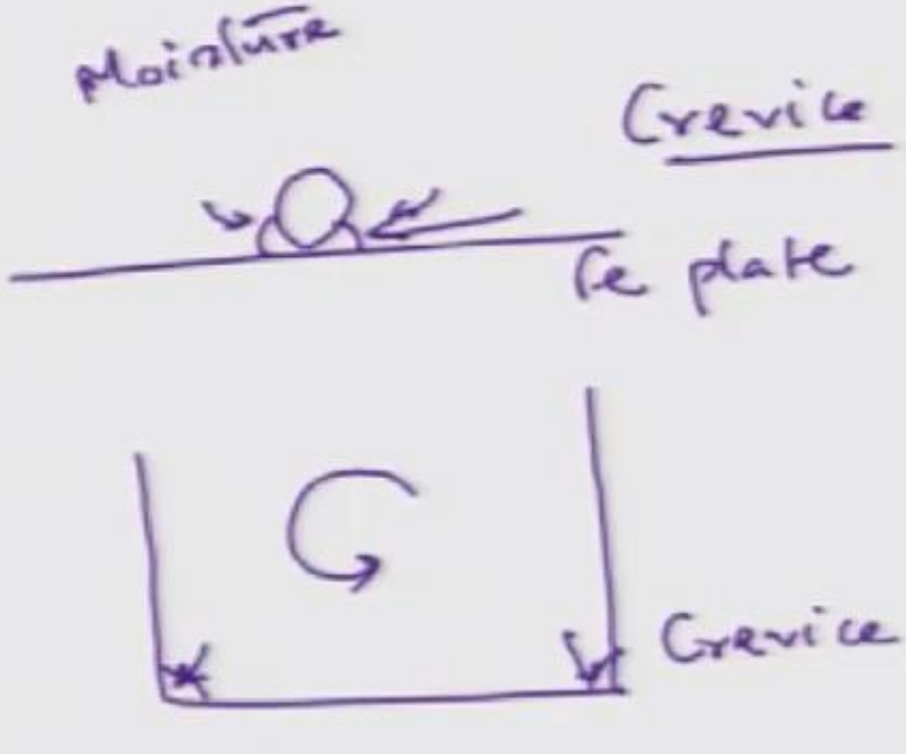
$\Delta V_{13} > \Delta V_{12}$

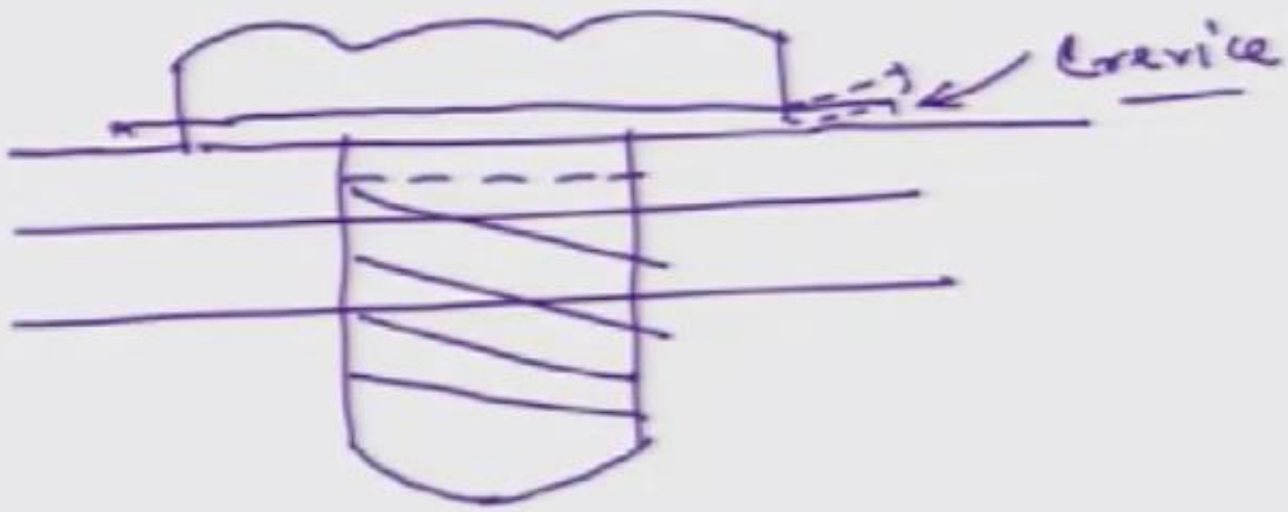
$\frac{M_1 - M_3}{M_1 - M_2}$


Stronger
than the parts
to be fastened


Zn
Fe
Zn
> 60°C
Active
part
Fe −2e
→ Fe2+
Zn
Noble
Fe
Noble
Zn
Active

Crevice Corrosion



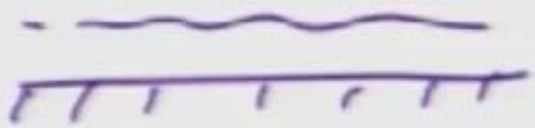


(1) Crevice
(2) Water ingress in the crevice
↓
Stagnant water

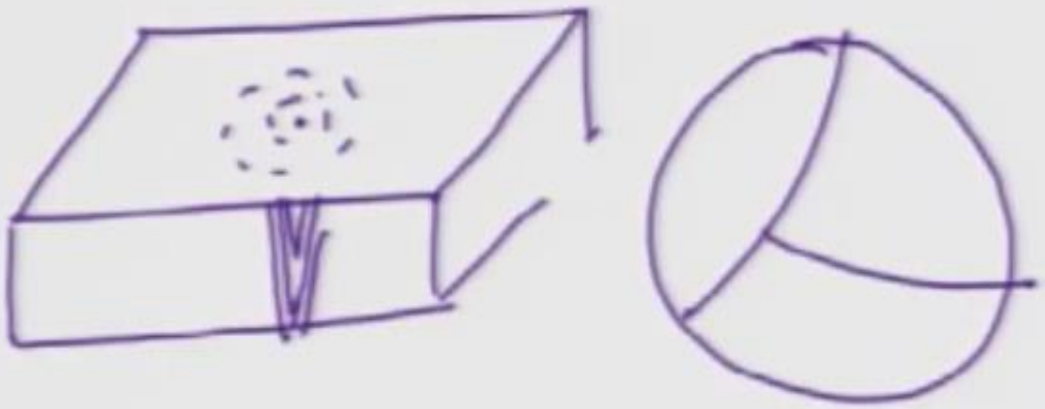
[(1) Crevice gap should be wide enough to get water inside
(2) Water inside crevice → stagnant.

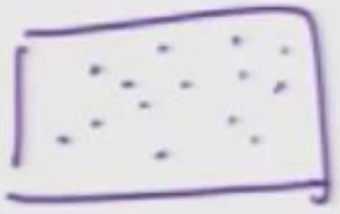
Pitting

1) Stagnant solution



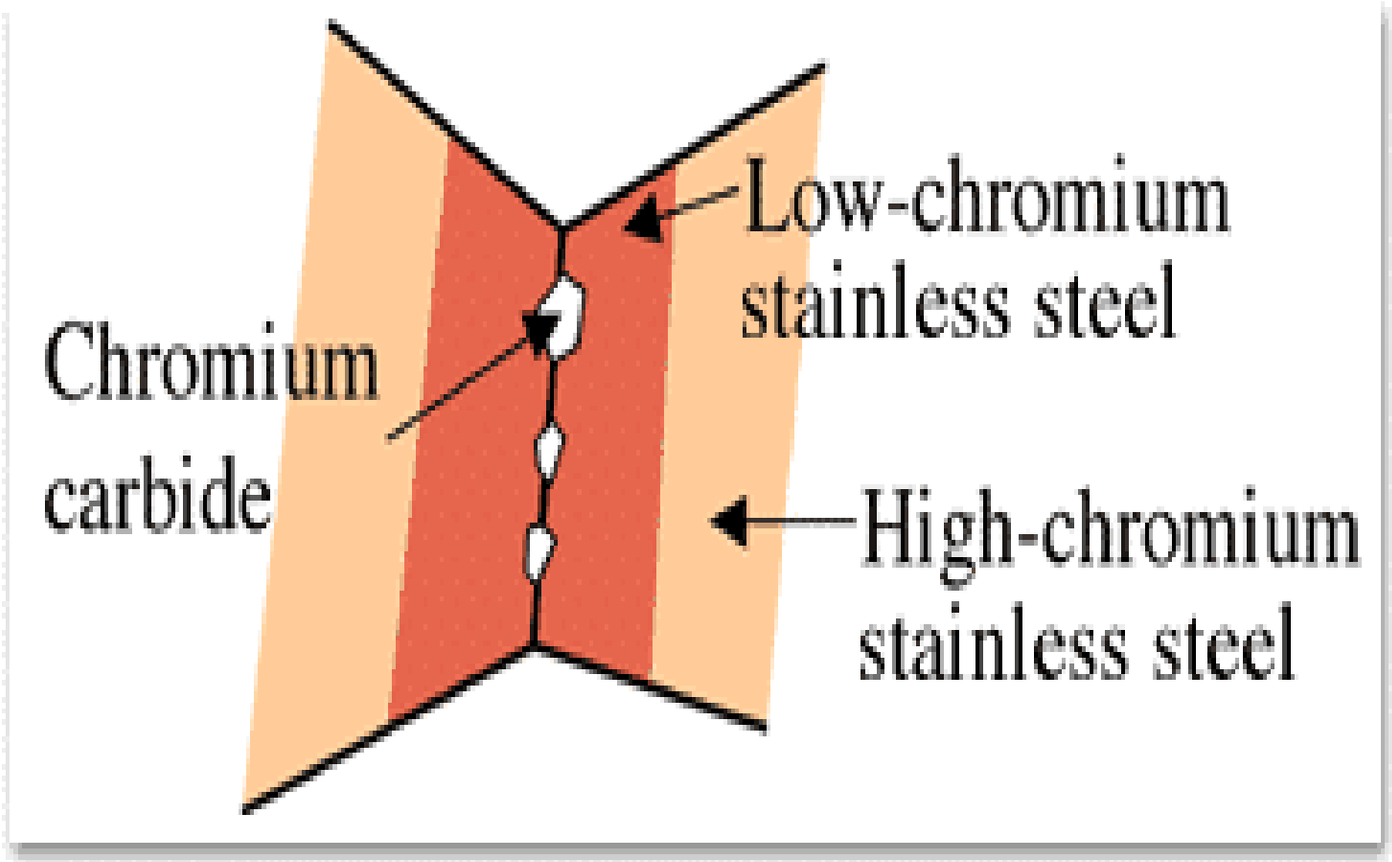
Initiation of pit happens on weak, active region of a metal

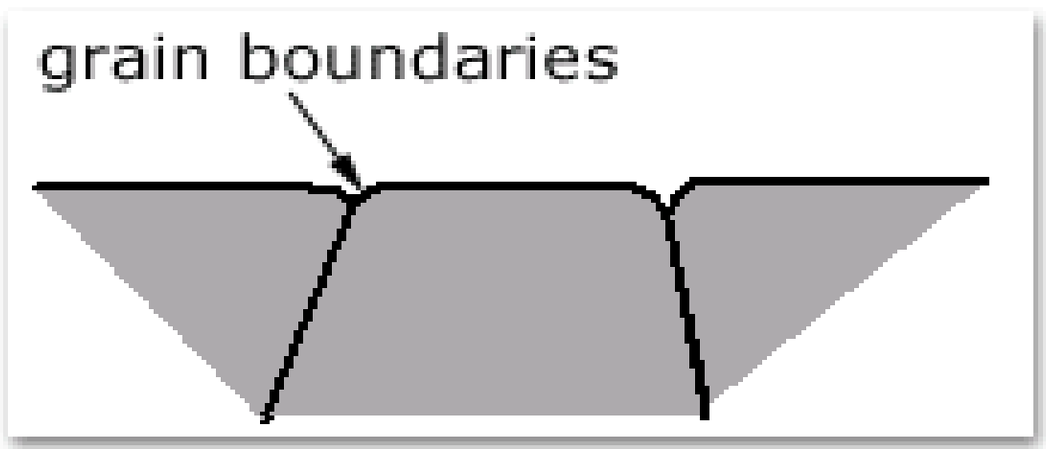




Intergranular Corrosion

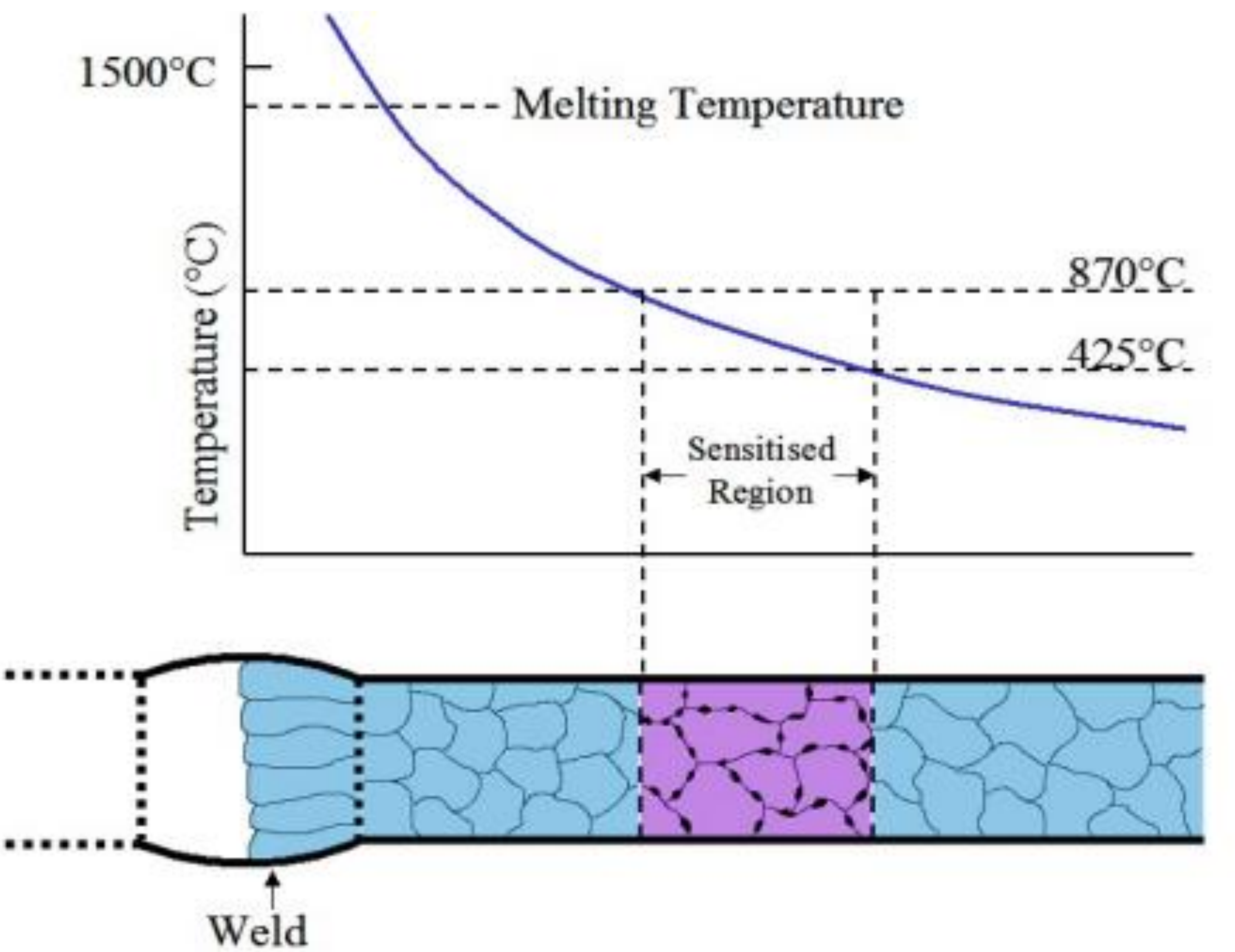
- Intergranular corrosion occurs when the grain boundaries in a metal form an anode and the interior of the grain acts as a cathode. In serious cases this can lead to the grains falling apart.
- This type of corrosion is a particular problem in stainless steels, however it can also occur in other metals.





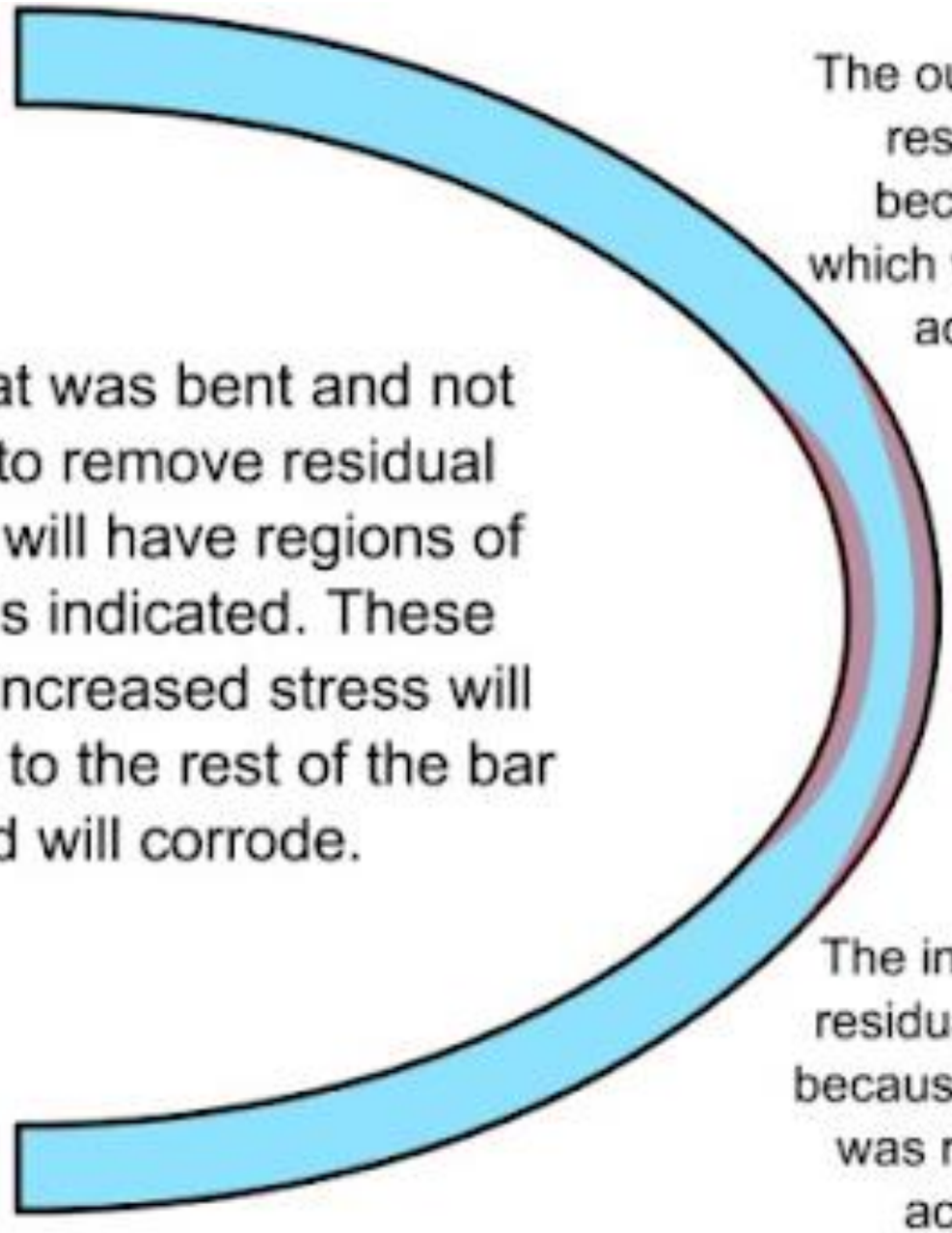
Intergranular Corrosion

- In stainless steels the problem occurs after the metal is heated to between 425°C and 870°C. During the heating, the chromium in the stainless steel reacts with carbon in the steel and forms particles of chromium carbide at the grain boundaries. The regions near the grain boundaries become depleted in chromium.
- When the area around a weld becomes sensitised, it is very susceptible to intergranular corrosion, and this is often termed weld decay.


1500°C
Melting Temperature
Temperature (°C)
870°C
425°C
Sensitised
Region
Weld

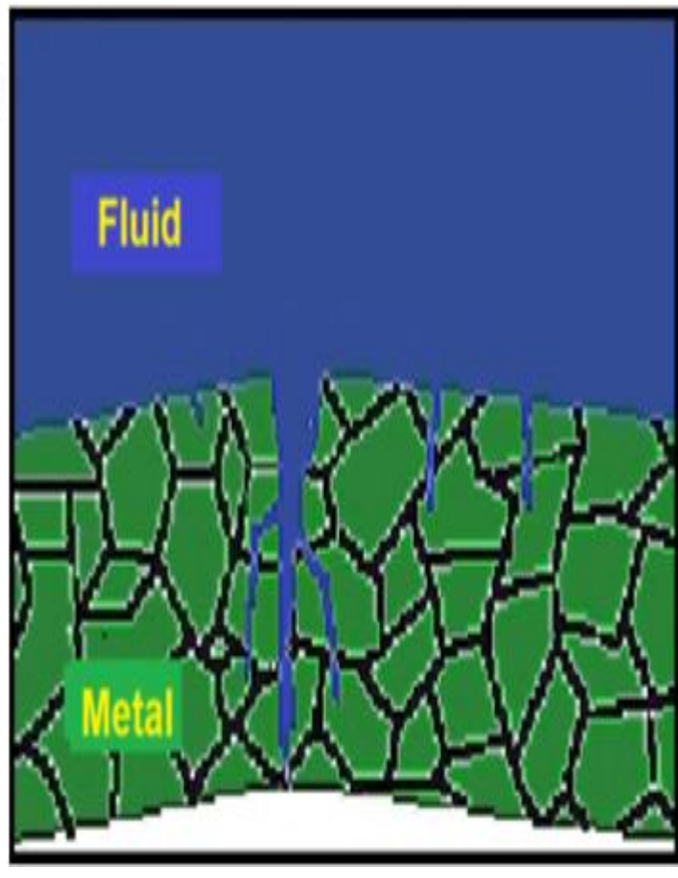
Stress Corrosion

A bar that was bent and not treated to remove residual stresses will have regions of stress as indicated. These areas of increased stress will be anodic to the rest of the bar and will corrode.



The outside of the bar will have residual tension stresses because this was the side which was required to stretch to accomodate the bend.

The inside of the bar will have residual compression stresses because this was the side which was required to compress to accomodate the bend.

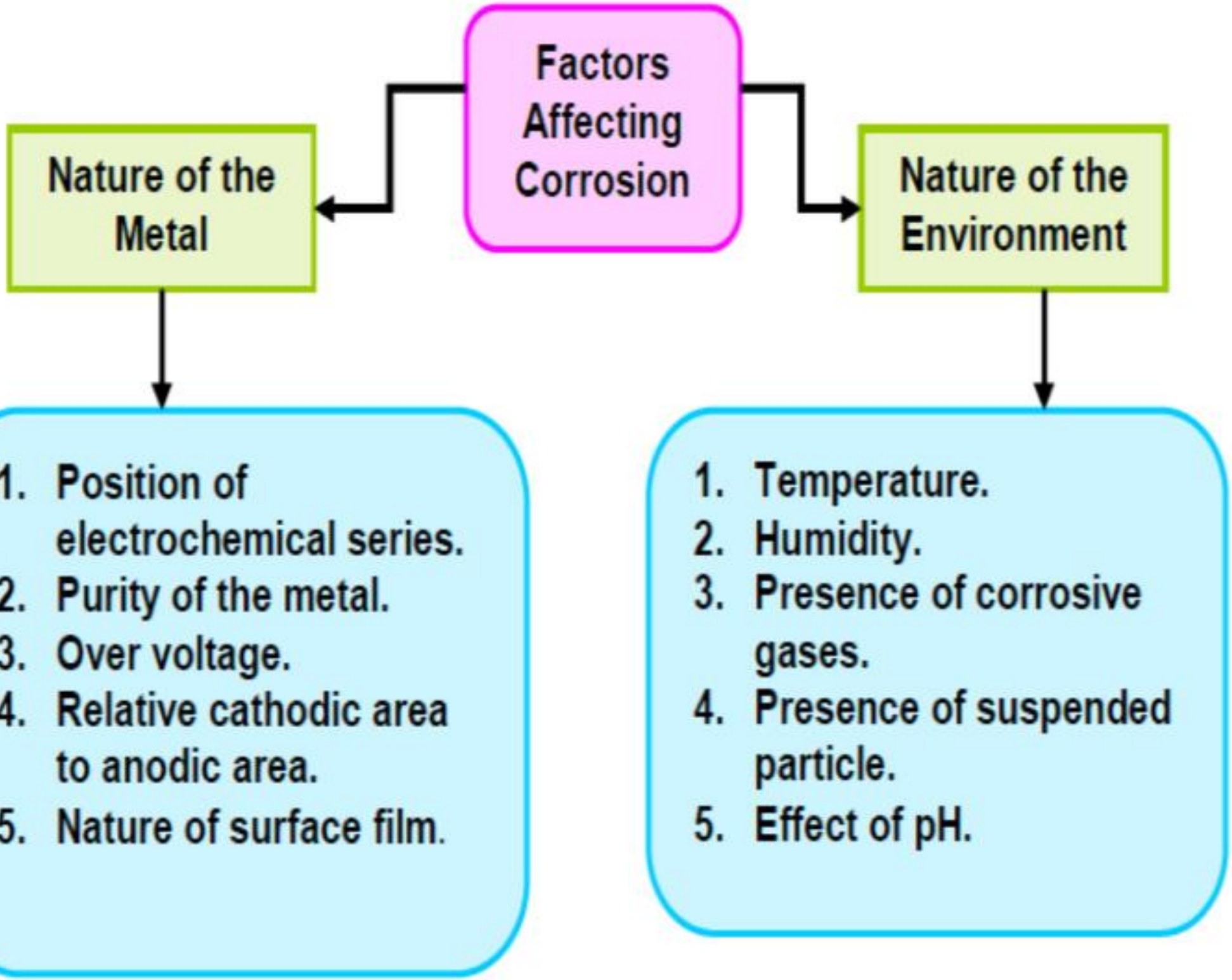


Stress corrosion cracking

Stress Corrosion

- Stress-corrosion occurs when a material exists in a relatively inert environment but corrodes due to an applied stress. The stress may be externally applied or residual.
- This form of corrosion is particularly dangerous because it may not occur under a particular set of conditions until there is an applied stress. The corrosion is not clearly visible prior to fracture and can result in catastrophic failure.
- Many alloys can experience stress corrosion, and the applied stress may also be due to a residual stress in the material.
- Stress corrosion cracking will usually cause the material to fail in a brittle manner, which can have grave consequences as there is usually little or no warning before the failure occurs.
- Stress corrosion is a form of galvanic corrosion, where stressed areas of the material are anodic to the unstressed areas of the material.
- Practically the best way to control stress corrosion cracking is to limit or reduce the stresses a material is under while it is in a corrosive atmosphere.

Factors affecting corrosion



Factors affecting corrosion

1. Presence of impurities in metals

Speed of corrosion increases with the presence of impurities in the metals because these impurities help in setting up the voltaic cells.

2. Presence of electrolyte

Electrolytes present in water also increases the rate of corrosion e.g. corrosion of iron in sea water takes place in large extent than in distilled water because sea water contains salts i.e.electrolytes.

Factors affecting corrosion

3. Position of metals in electrochemical series

Highly reactive metals undergo corrosion faster than least reactive metals. Reactivity of metals can be found from the electrochemical series.

e.g. Au → Cu → Pb → Fe → Zn → Al → Mg → Na → K

Reactivity increases ⟶

4. Presence of carbon dioxide in water

Presence of carbon dioxide in natural water also increases the rusting of iron because it acts as an electrolyte and increases the flow of electron from one place to another.

Factors affecting corrosion

5. Presence of protective coating

When the iron surface is coated with the metal, which is more reactive than the iron, then the rate of corrosion is retarded e.g. when iron is coated with zinc, iron is protected from rusting.