# SS INSTITUTE OF PHARMACY

# Pharmaceutical Engineering

## UNIT-5

TOPICS:

- Materials of Pharmaceutical Plant Construction
- Corrosion and its Prevention
- Metals

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# INTRODUCTION

- For manufacturing of pharmaceuticals, bulk drugs, antibiotics, biological products etc., number of equipments are used. The equipments are generally used for processing and packing of products.
- A wide variety of materials are used for manufacturing of theses equipments. Some products are highly acidic while some are highly alkaline. Some products such as storage of biological products need to be handled carefully.

- These factors affect the success or failure of new chemical plant. If container will not compatible with material then there are chances of contamination.
- So, the proper choice of material is very important both for construction of processing equipments as well as containers and closers for storage of finished products. The choice based on expert advice, previous experience and laboratory tests.

# FACTORS AFFECTING DURING MATERIALS SELECTED FOR PHARMACEUTICALS PLANT CONSTRUCTION

## 1. Chemical Factors

Each time a chemical is placed in a container or equipment, the chemical is exposed to the construction material of the container or equipment. Therefore, the material of construction may contaminate the product (*contamination*) or the product may destroy the material of construction (*corrosion*).

### a. Product contamination:

The leaching of glass can make the aqueous product alkaline. This alkaline medium may catalyze the decomposition of the product. Heavy metals, such as lead, inactivate penicillin.

### b. Corrosion of construction materials

The products can be corrosive in nature. They can react with the material and can destroy it. This can decrease the life of the equipment. Extreme pH, strong acids, strong alkalis, powerful oxidizing agents, tannins etc., reacts with the materials, therefore, some alloys that having special chemical resistance are used.

## 2. Physicals Factors

### a. Strength

- Iron and steel can satisfy these properties. The tablet punching machine, the die and the upper and lower punches are made of stainless steel to withstand very high pressure. Glass, though has strength but fragile in nature.

### b.Mass:

For transportation, lightweight packaging materials are used. Plastic, aluminum and paper packaging materials are used to package pharmaceutical products.

### c. Wear properties:

- When there is a possibility of friction between two surfaces, the softer surface disappears and these materials contaminate the products. For example, during milling and grinding, grinding surfaces can wear out and contaminate the powder. When pharmaceutical products of very high purity are required, grinding surfaces of ceramic and iron are not used.

**d. Thermal conductivity**:

In evaporators, dryers, stills and heat exchangers, the materials used should have very good thermal conductivity. In this case, iron, copper or graphite tubes are used for effective heat transfer.

**e. Ease of fabrication**:

During the manufacturing of equipment, the materials undergo various processes, such as casting, welding and forging. For example, glass and plastic can be easily moulded into containers of different shapes and sizes. The glass can be used as coating material for reaction vessels.

**f. Sterilization :** In the production of parenterals, ophthalmics and bulk drugs, all equipment must be sterilized properly to avoid microbial contamination of the product. This is usually done by introducing high pressure stream. **The material must withstand at high temperature (121$^0$C) and pressure (15 pounds per square inch). If there are rubber materials, it must be vulcanized to withstand the light temperature.**

**g. Cleaning**:

Smooth and polished surfaces facilitate ease in cleaning. After completing the operation, the equipment is thoroughly cleaned so that the previous product cannot contaminate the next product. The surfaces of glass and stainless steel can be smooth and polished.

**h. Transparency**:

In the parenteral and ophthalmic containers, the particles, if any, are observed with polarized light. The walls of the containers must be transparent to see through it. The glass is used as perfect material.

## 3. Economic Factors

The initial cost of the equipment depends on the material used. Several materials may be suitable for construction from the physical and chemical point of view, but of all the materials only the cheapest material for the construction of the equipment is chosen. **Materials that require a lower maintenance cost are used because in the long term it is economical. The material used for construction of plant is classified as metals (ferrous and non ferrous) and non metals (organic and inorganic).**

# CORROSION

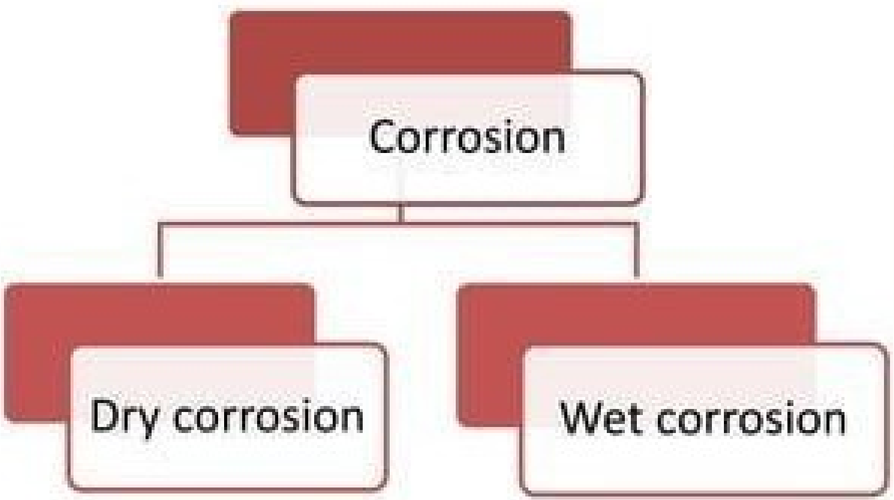
- It is defined as the reaction of a metallic material with its environment, which causes a measurable change to the material and can result in a functional failure of the metallic component or of a complete system.
- $H_2O + CO_2 + Fe^{3+} + O_2 \rightarrow Fe_3O_4$ (ferrous oxide)

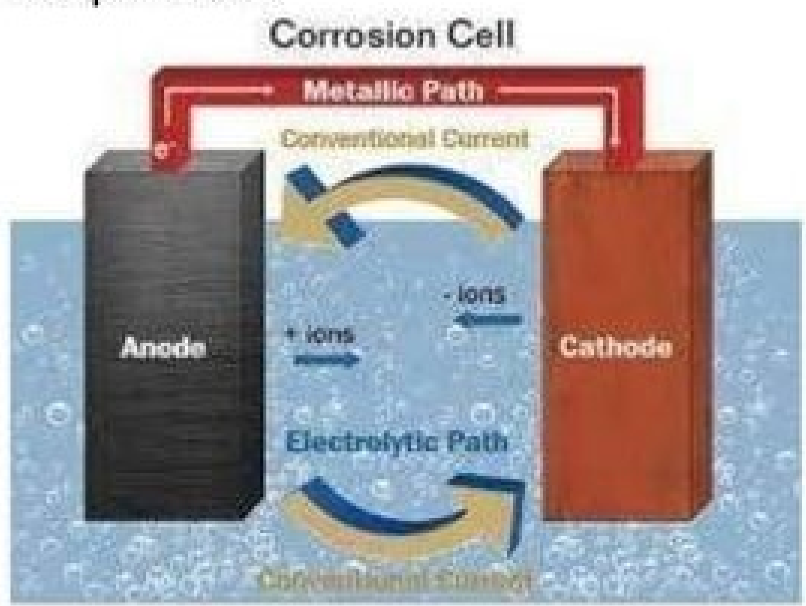
**CAUSES** : Exposure of surface to air, water and caustic chemicals are the measure causes of corrosion.

Corrosion can be either :

1. **Dry Corrosion**: It involves the direct attack of gases and vapor ($H_2$, $N_2$, $O_2$, $CO_2$) on the metals through chemical reactions. As a result an oxide layer is formed over the surface. This type of corrosion is not common.

2. **Wet Corrosion**: This corrosion involves purely electrochemical reaction that occurs when the metal is exposed to an aqueous solution of acid and alkali. The moisture and oxygen are also responsible.



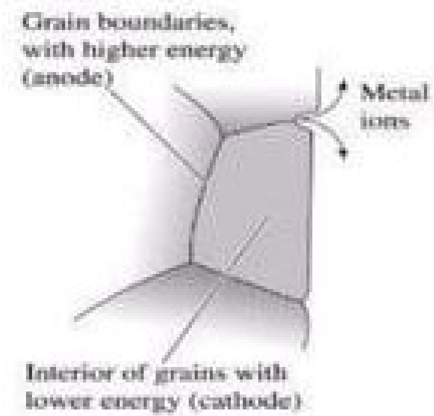



# TYPES OF CORROSION

**1. General corrosion**

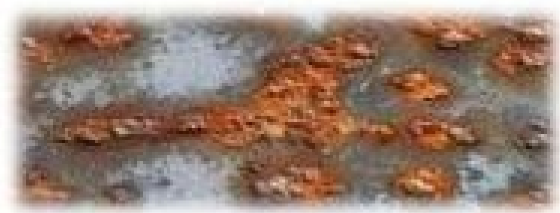
- When corrosion is generally confined to a metal surface as a whole, it is known as general corrosion. This corrosion occurs uniformly over the entire exposed surface area. e.g. swelling, cracking, softening etc. of plastic materials.

**2. Localised corrosion (Observed in different location of metallic surface)**




**a.Inter-granular corrosion**:

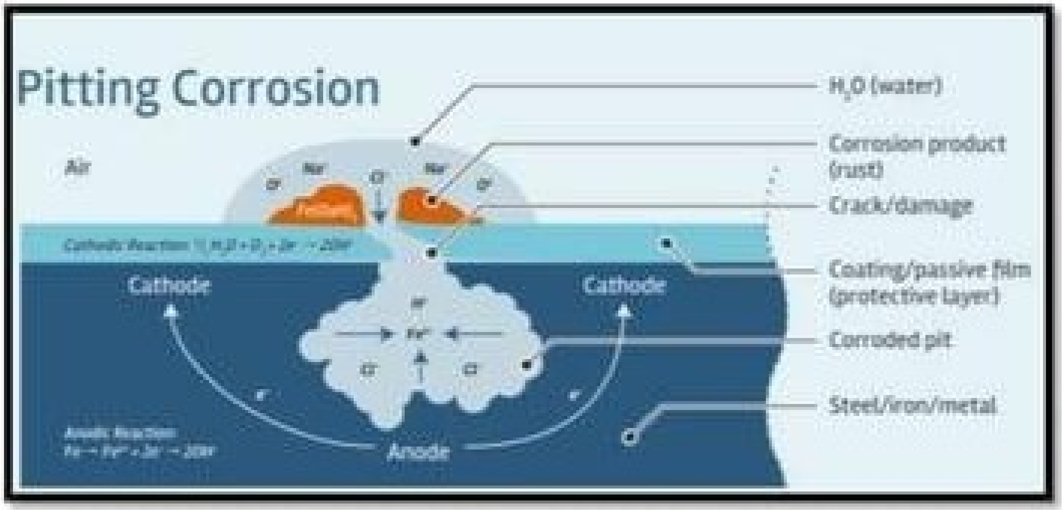
- During heat treatment or welding, some components get precipitated at the grain boundary of the metal. These boundaries act as anodes and grains as cathodes. So corrosion of anode region occurs.



**b.Pitting corrosion**:

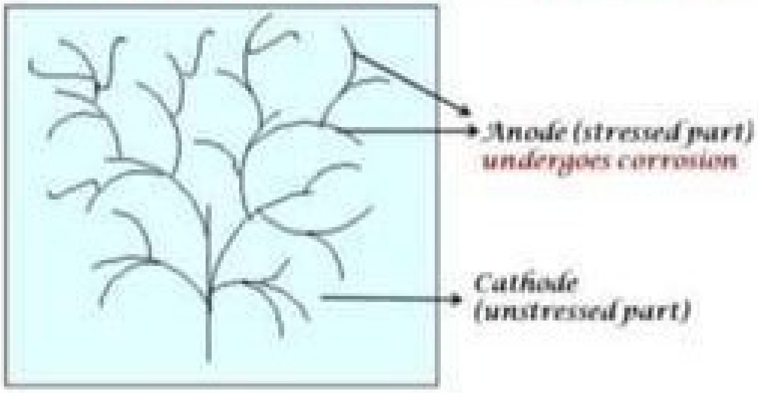
- On metal surface small holes or pits are created due to local corrosion and these pits increase in size rapidly. In the pits the metals dissolve rapidly especially by chlorine and chloride ions.

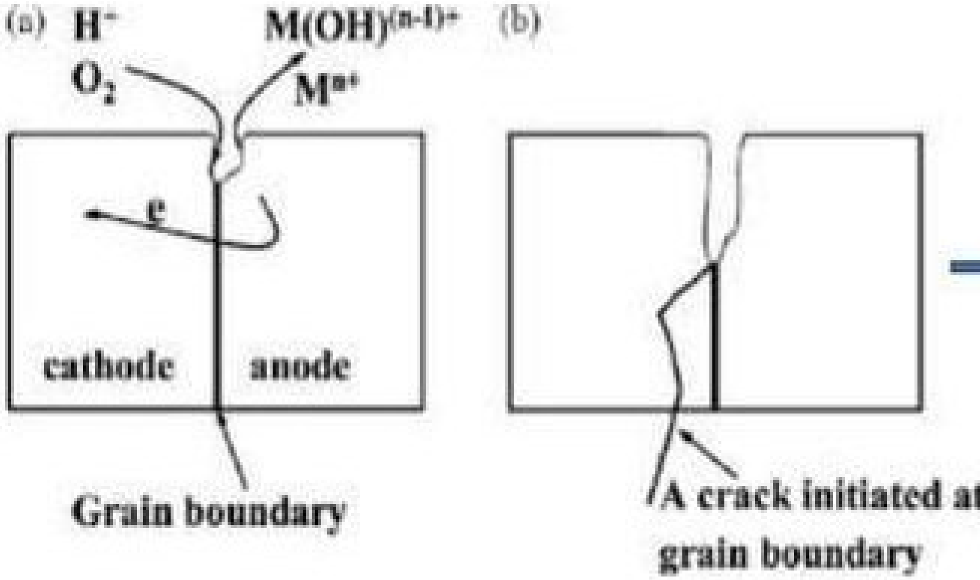
Alloy of auminium + aq. Solution $\longrightarrow$ cavities (in presence of chlorides)




**c. Stress corrosion**: Certain area of metal may be subjected to thermal, mechanical or chemical stresses. The surface area becomes anode and acts as corrosion area.

# STRESS CORROSION CRACKING




Crack due to stress corrosion

d. **Fretting corrosion**: Equipment showing high vibrations destroys the surface of metal (e.g. steels balls in ball-bearing) by mechanical hitting.

e. **Corrosion fatigue**: Cyclic stress breaks the protective film, so corrosion increases.

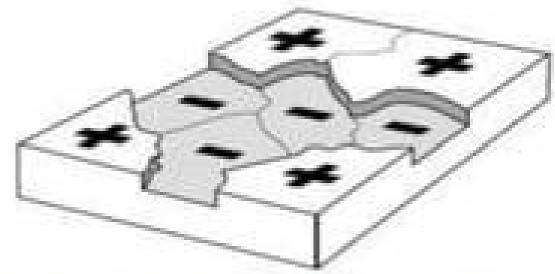
**3. Biological corrosion**

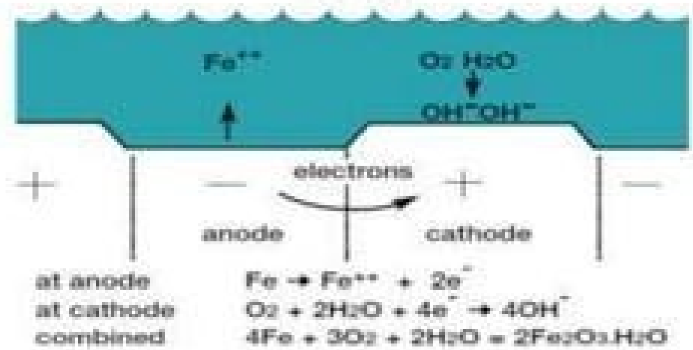
- Metabolic action of micro-organisms can either directly or indirectly cause deterioration of a metal is called Biological corrosion.
- These corrosion occurs due to :

- **Creating electrolyte concentration cells on the metal surface.**
- **Influencing the rate of anodic / cathodic reactions.**
- **Sulphates are converted in to hydrogen peroxide (H2S) because of action of reducing bacteria on them. This reacts with iron to produce ferrous sulphide (FeS). Thus the iron gets corroded.**

**4. Structural corrosion :**

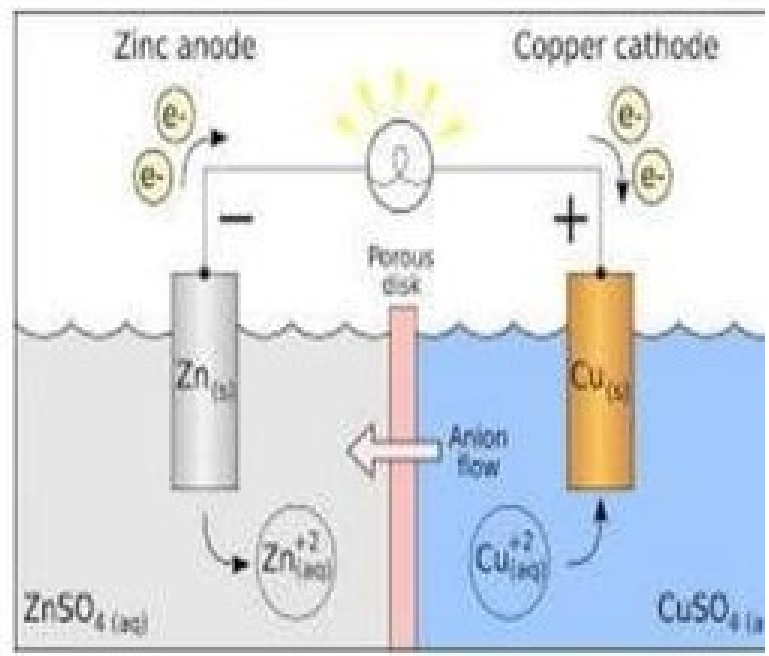
- The strength is reduce on account of corrosion. Examples, graphite corrosion (occurs in grey cast iron) and dezincification ( occurs in brass).






**5. Galvanic corrosion :**

- It is associated with the flow of current to a less active metal (copper cathode) from a more active metal (zinc anode).



# FACTORS INFLUENCING CORROSION

- **pH of the Solution**
  - Iron dissolves rapidly in acidic pH. Aluminium and zinc dissolves both in acidic and alkaline pH. Noble metals are not affected by pH e.g. gold and platinum.
- **Oxidizing Agents**
  - Oxidizing agents may accelerate the corrosion of one class of materials whereas retard another class, Example: $O_2$ reacts with $H_2$ to form water. $H_2$ is removed, corrosion is accelerated. Cu in NaCl solution follows this mechanism also.
- **Velocity**
  - When corrosive medium moves at a high velocity along the metallic surface, the rate of corrosion increases because of:
- Corrosion products are formed rapidly and washed away rapidly to expose new surface for corrosion reaction.
- Accumulation of insoluble films on the surface is prevented.
- **Surface Films**
  - Thin oxide films are formed on the surface of stainless (rusting). These films absorb moisture and increase the rate of corrosion.

# PREVENTION OF CORROSION

## 1. Material Selection

- Pure materials have less tendency towards pitting, but they are expensive and soft. Therefore, only aluminium can be used in pure form.
  - Improved corrosion resistance can be obtained by adding corrosion resistant elements. For example inter-granular corrosion occurs in stainless steel. This tendency can be reduced by addition of small amount of *titanium*.
  - **Nickel, copper and their alloys are used in non-oxidizing environment, whereas chromium containing alloys are used in oxidizing environment.**
  - Materials those are close in electrochemical series should be used for fabrication.
  - Corrosive materials are taken with suitable material of construction.

**2. Proper Design of Equipment**

Corrosion can be minimized in the following conditions:

- Design for complete drainage of liquids.
- Design for ease of cleaning.
- Design for ease of inspection and maintenance.
- A direct contact between two metals should be avoided. They may be insulated from one another.

3. **Coating and lining: Non metallic coatings and lining can be applied on steel and other materials of construction to prevent corrosion.** The metals are more prone to corrosion. To combat corrosion in metals, non metals coating or lining should be used.

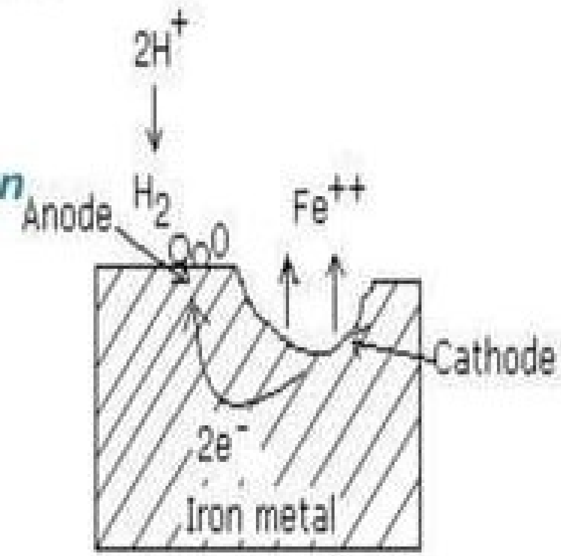
| LININGS | USES |
|---|---|
| Tin Plated Steel | Food Containers |
| Lead(Pb) coating | Roofings |
| Aluminium (Al) coated steel | High temp. condition |
| Zinc (Zn ) | Other atmospheric conditions |

4. **By changing the environment:** Corrosion can be prevented by removing air from boiler feed water which prevent steel from the corrosive effect of water. In case of nickel based alloy the pumping of inert gas reduce air or oxygen content.
5. **Use of Corrosion Inhibitors:** Corrosion inhibitors are used to decrease corrosion of metals. The inhibitors are used in critical amount (less than 0.1% by weight). For example: Chromates, phosphates and silicates are used to protect iron and steel in aqueous solutions.
6. **Cathodic protection**
7. **Anodic protection**

# Theories of Corrosion

1. **Corrosion Reaction on Single Metal**

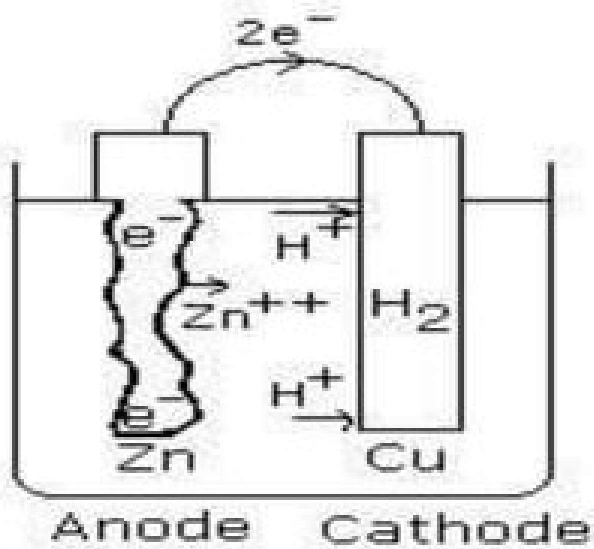
- Corrosion occur on a piece of iron in hydrochloric acid. Anodic and cathodic areas formed on the surface of iron owing to surface imperfections or due to variation in the external environment
- **Reaction at anode:**
- *$Fe \longrightarrow Fe^{++} + 2e^-$ (indicated by rough surface oxidation*
- **Reaction at cathode:**
- *$2H^+ + 2e^- \longrightarrow H_2$ (formation of bubbles at the surface)*
- *Overall reaction: $Fe + 2H_2O \longrightarrow Fe(OH)_2 + H_2$*



## 2. Corrosion Reactions between Metals

if both the metals are connected with a wire the reaction will proceed. Anode metal will be corroded and hydrogen will form at the cathode.

- For example if a zinc and a copper plate is immersed in an acidic medium then zinc will form anode and will be corroded while hydrogen will be formed at copper plate.
- *Anode reaction*: $Zn \rightarrow Zn^{++} + 2e^-$.
- *Cathode reaction*: $2H^+ + 2e^- \rightarrow H^2$
- So anode will be corroded and hydrogen will be evolved at cathode.
- 



3. **Corrosion Involving Oxygen**

- The oxygen dissolved in the electrolyte can react with accumulated hydrogen to form water. Depletion (reduction) of hydrogen layer allows corrosion to proceed.
- *At cathode:* $O_2 + 2H_2 \longrightarrow 2H_2O$
- The above reaction takes place in acid medium. When the medium is alkaline or neutral oxygen is absorbed. The presence of moisture promotes corrosion.

# Metals.

**<u>Exercise 1:</u>**

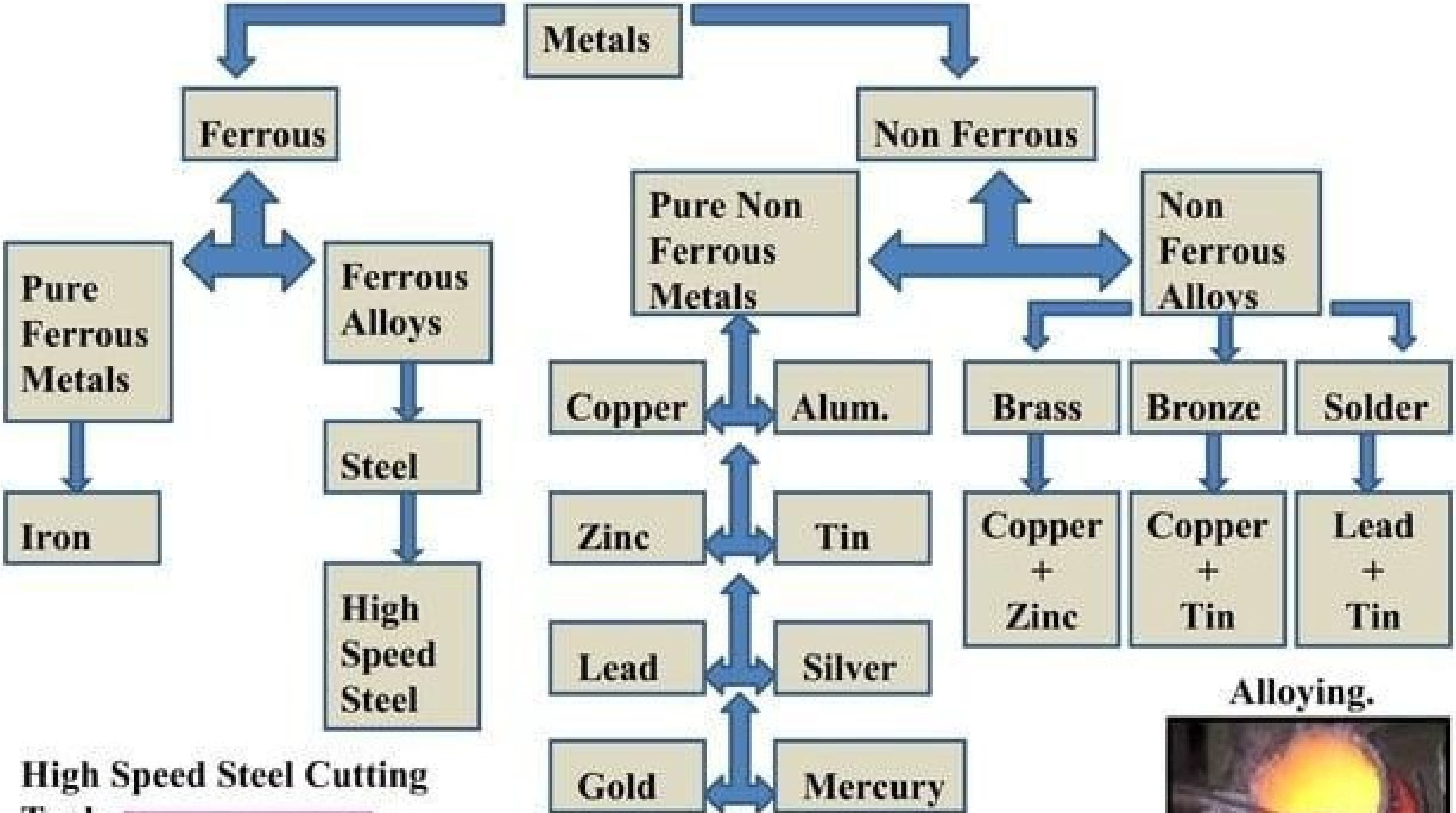
**Make a list of all the different metals that you know about.**

# Metals.

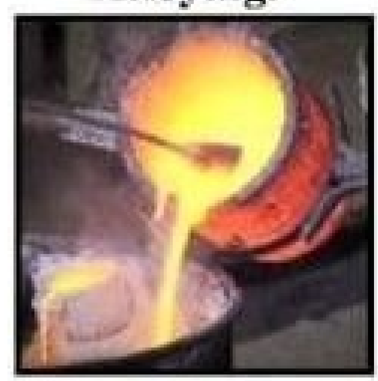
**Two main groups,**

**1.Ferrous.**

**2.Non-Ferrous.**




Alloying.



High Speed Steel Cutting Tools

Mercury is the only non ferrous metal that is liquid at room temperature.

# Ferrous Metals.

**Ferrous metals:**

**Ferrous metals are metals that consist mostly of iron and small amounts of other elements. Ferrous metals are prone to rusting if exposed to moisture. Ferrous metals can also be picked up by a magnet. The rusting and magnetic properties in ferrous metals are both down due to the iron. Typical ferrous metals include mild steel, cast iron and steel.**

**Examples:**

1. Mild Steel.
2. Cast Iron.
3. High Carbon Steel.
4. High Speed Steel.
5. Stainless Steel.

**Rusting.**

**Magnetism.**

# Ferrous Metals.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Mild Steel.**<br>A ductile and malleable metal. Mild steel will rust quickly if it is in frequent contact with water. | Used as Nuts and bolts, Building girders, car bodies, gates, etc. | 1600°C |




# Ferrous Metals.

**Metal Type.**

**Cast Iron.**
**Is a very strong metal when it is in compression and is also very brittle. It consists of 93% iron and 4% carbon plus other elements.**

**Metal Uses.**

**Used as car Brake discs, car cylinders, metalwork vices, manhole covers, machinery bases eg: The pillar drill.**

**Melting Point.**

**1200°C**

# Ferrous Metals.

| Metal Type. | Metal Uses. | Melting Point. |
| --- | --- | --- |
| **High Carbon Steel .**<br>It is a very strong and very hard steel that has a high resistance to abrasion. Properties – Up to 1.5% carbon content. Very tough. | Used for hand tools such as screwdrivers, hammers, chisels, saws, springs and garden tools. | 1800°C |

# Ferrous Metals.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **High Speed Steel.** HSS is a metal containing a high content of tungsten, chromium and vanadium. However it is very brittle but is also very resistant to wear. | Used for drill bits and lathe cutting tools. It is used where high speeds and high temperatures are created. | 1400°C |

# Ferrous Metals.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Stainless Steel.**<br>Stainless steel is very resistant to wear and water corrosion and rust.<br>Properties – It is an alloy of iron with a typical 18% chromium 8% nickel and 8% magnesium content. | Used for kitchen sinks, cutlery, teapots, cookware and surgical instruments. | 1400°C |


# Classwork /Homework.

1). What are the properties of a ferrous metal?

2.) What is cast iron used for?

3.) Why is it good to make hammers out of high carbon steel?

4.) Why is it good to make cutlery out of stainless steel?

5.) List one application and one property of the following alloy steels:

(i) Stainless Steel;

(ii) High Speed Steel.

# Non – Ferrous Metal.

**Non-Ferrous Metals:**
**Non-ferrous metals are metals that do not have any iron in them at all. This means that Non-ferrous metals are not attracted to a magnet and they also do not rust in the same way when exposed to moisture. Typical Non-ferrous metals include copper, aluminium (coke cans), tin and zinc.**

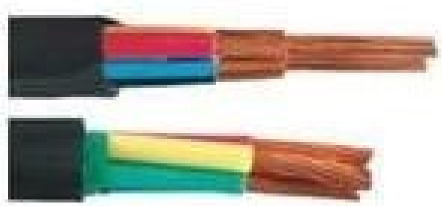
**Examples:**
1. Aluminium.
2. Copper.
3. Zinc.
4. Tin.
5. Lead.
6. Silver.
7. Gold.
8. Magnesium.

# Non – Ferrous Metal.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Aluminium.**<br>It tends to be light in colour although it can be polished to a mirror like appearance. It is very light in weight. | Used for saucepans, cooking foil, window frames, ladders, expensive bicycles. | 660°C |

# Non – Ferrous Metal.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Copper.** It is a ductile and malleable metal. It is often red / brown in colour. It is a very good conductor of heat and electricity. | Used for plumbing, electric components, cookware and roof coverings. | 1084°C |



# Non – Ferrous Metal.

| Metal Type. | Metal Uses. | Melting Point. |
| --- | --- | --- |
| **Zinc.** It is very resistant to corrosion from moisture. However zinc is a very weak metal and is used mainly for coating steel. | Used as a coating on screws, steel buckets etc It is also used to galvanize steel. | 419°C |

# Non – Ferrous Metal.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Tin.** It is a very ductile and very malleable metal. It is resistant to corrosion from moisture. It is bright silver in appearance. Tinplate is steel with a tin coating. | Used as a coating on food cans, beer cans. Used as whistles, tin foil and soldering. | 231°C |

# Non – Ferrous Metal.

| **Metal Type.** | **Metal Uses.** | **Melting Point.** |
| --- | --- | --- |
| **Lead.** It is a soft, malleable metal. It is also counted as one of the heavy metals. Lead has a bluish-white color after being freshly cut, but it soon tarnishes to a dull grayish color when exposed to air. | Used for roof flashing. Also used for batteries and for X-ray protection. Lead is used for its weight in many ways. | 327°C |

# Classwork /Homework.

(a) Name the non-ferrous metal used to make cooking pots.

(b) Name the metal used for plumbing.

(c) What metal is used to galvanize steel.

(d) A heavy metal used in batteries.

(e) What is tinplate.

# Non – Ferrous Metal.

| <u>Metal Type.</u> | <u>Metal Uses.</u> | <u>Melting Point.</u> |
|---|---|---|
| <u>Silver.</u><br>A soft, white, lustrous transition metal, it has the highest electrical conductivity of any element and the highest thermal conductivity of any metal. The metal occurs naturally in its pure, free form. | Used for jewelry and high quality cutlery. Also used for currency coins and sports trophies. Used in mirrors as a reflective metal. | 961°C |

# Non – Ferrous Metal.

**Metal Type.**

**Gold.**

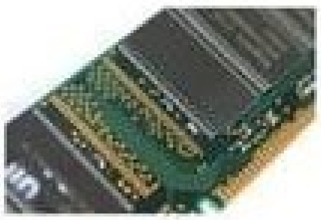
**Gold is a dense, soft, shiny, malleable and ductile metal. Pure gold has a bright yellow color and luster traditionally considered attractive, which it maintains without oxidizing in air or water. Gold resists attacks by individual acids It won't tarnish, discolor, crumble, or be affected by most solvents.**

**Metal Uses.**

**Used mainly for jewelry. Also used in computers as a conductor. Used for its reflective powers to protect satellites.**

**Melting Point.**

**1337°C**



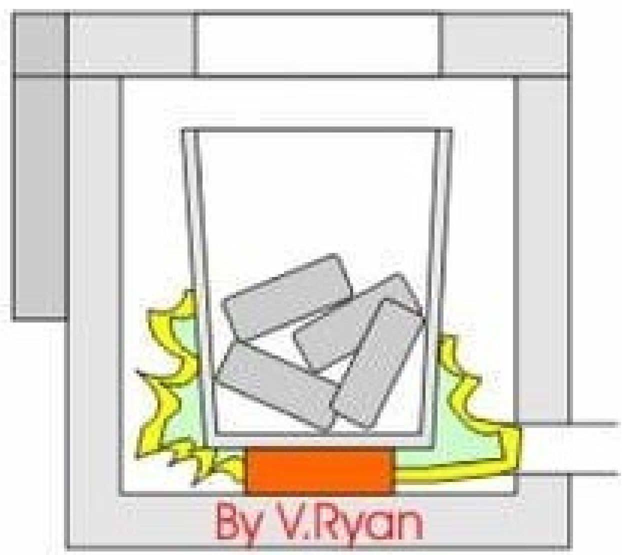
# Non – Ferrous Metal.

| Metal Type. | Metal Uses. | Melting Point. |
|---|---|---|
| **Magnesium.** Magnesium is a fairly strong, silvery-white, light-weight metal (one third lighter than aluminum) that slightly tarnishes when exposed to air. In a powder, this metal heats and ignites when exposed to moisture and burns with a white flame. | Magnesium is used in pyrotechnic (i.e. fireworks). It is alloyed with other metals to make them lighter and more easily welded. | 648°C |


# Non – Ferrous Metal Alloys.

**Non-Ferrous Metal Alloys:**
**Non-ferrous metal alloys are metals that are a mixture of two or more metals. The main ones in everyday use are,**

**Brass.**
**Bronze.**
**Solder.**




**Heating metals in a furnace to form an alloy.**

# Non – Ferrous Metal Alloys.

**Metal Type.**

**Brass.**

**Brass is a mixture of copper and zinc. Copper is the main component, and brass is usually classified as a copper alloy. The color of brass varies from a dark reddish brown to a light silvery yellow. Brass is stronger and harder than copper, but not as strong or hard as steel. It is easy to form into various shapes, a good conductor of heat, and generally resistant to corrosion from salt water.**


**Metal Uses.**

**Brass is used to make water fittings, screws, radiators, musical instruments, and cartridge casings for firearms.**

**Melting Point.**

**940°C**

# Non – Ferrous Metal Alloys.

| Metal Type. | Metal Uses. | Melting Point. |
| --- | --- | --- |
| **Bronze.** Bronze is a metal alloy consisting primarily of copper, usually with tin as the main additive. It is a hard and brittle metal. It has a very high resistance to corrosion. | Used for ship propellers and underwater fittings. Also used for statues and medals. - | 950°C |

# Non – Ferrous Metal Alloys.

| Metal Type. | Metal Uses. | Melting Point. |
| --- | --- | --- |
| **Solder.** Solder is a fusible metal alloy used to join together metal work pieces and having a melting point below that of the work pieces. It is an alloy of Lead and Tin. | Solder is used for electronics, plumbing, jewelry making and repair processes where metal parts cannot be effectively or safely welded. | 200°C |

# Classwork /Homework.

**(a) List the two metals used to make each of the following alloys:**

**Brass;**
**Solder;**
**Steel.**

**(b) Suggest one application for each of the alloys listed.**

**(c)Identify the alloy used to manufacture each of the objects shown.**

**(d) Redraw the given table into your answer book. Complete the table by naming the alloys and listing one important property of each.**

| Composition. | Alloy. | Property. |
|---|---|---|
| Copper + Zinc | | |
| Iron + Carbon | | |
| Lead + Tin | | |

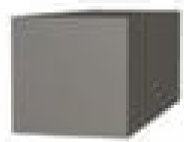
**Metal pieces after mining and separation from their ores.**
**(Note: Carbon and Phosphorous are non metals, while Silicon is a semi-metal)**

# Metal Shapes.

**Metal can be provided in various shapes and sizes. Some examples of these are shown below.**

**Round Solid.**

**Square Solid.**



**Hexagonal Solid.**

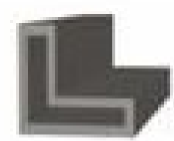
**Angle Iron Solid.**

**Round Hollow. (Tube)**

**Square Hollow. (Box Iron)**

**Hexagonal Hollow.**

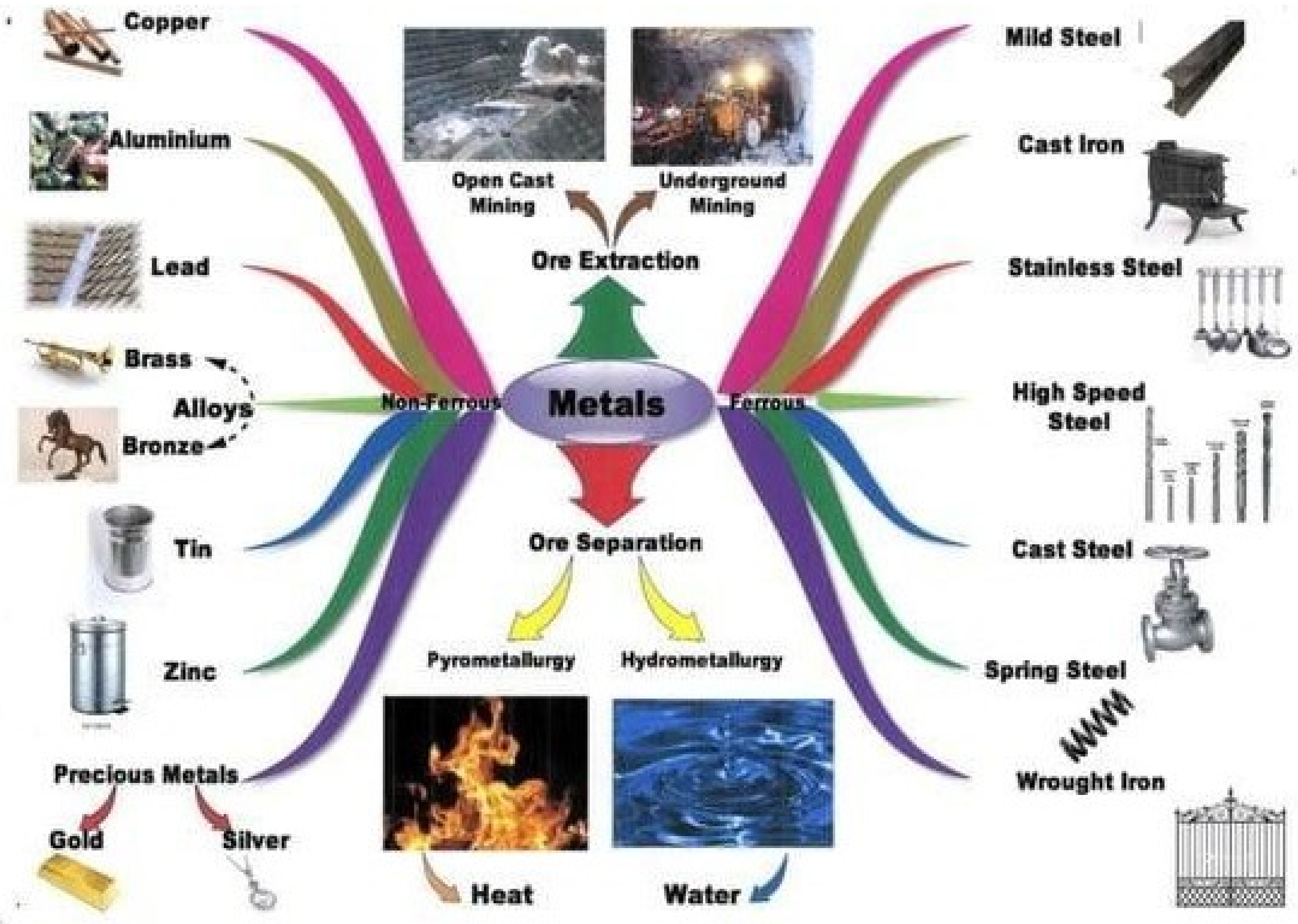
**Angle Iron Hollow.**



# Metals in Everyday Use.

**Below is a list of metals that would be used in the manufacturing of a bicycle.**

# Revision Work/Metals.




Thank you