Metals & Non-Metals
Metallurgy and Metallurgical Process

METALLURGY:

The process of extracting metals from their ores and refining them for use is known as metallurgy. In other words, the process of obtaining a metal from its ores is called metallurgy of the metal.

Metallurgical Operations

The various steps used in metallurgy are :

(1) Enrichment or dressing of the ore.
(2) Conversion of the enriched ore into the oxide of metal.
(3) Extraction of metal from the metal oxide.
(4) Refining or purification of the metal.

(1) Enrichment of Ores :

Ores mined from the earth are usually contaminated with large amounts of impurities such as soil, sand, etc., called **gangue or matrix**. The impurities must be removed from the ore prior to the extraction of the metal. The processes used for removing the gangue from the ore are based on the differences between the physical or chemical properties of the gangue and the ore. Different separation techniques are accordingly employed.

(i) Hydraulic washing
(ii) Froth floatation
(iii) Magnetic separation
(iv) Chemical separation/ reaching

(2) Conversion of the enriched ore into the oxide of metal

After concentration the ore is generally subjected to calcination or roasting, depending upon nature of ore.

Calcination : It is the process of heating the ore in a limited supply of air, at a temperature below its melting point.

(i) Volatile impurities are expelled.

(ii) Moisture is expelled.

(iii) Carbonate ores changes into oxide ores.

$$\underset{\text{Bauxite}}{Al_2O_3.2H_2O(s)} \longrightarrow Al_2O_3(s) + 2H_2O(g)$$

$$ZnCO_3(s) \longrightarrow \underset{\text{Calamine}}{ZnO(s)} + CO_2(g)$$

Calcination is carried out in case of carbonate ores or hydrates of oxide ores.

Roasting : It is the process of heating the ore in the excess supply of air, at a temperature below it melting point.

This process results in the following changes.

(i) Volatile impurities are expelled.

(ii) Moisture is expelled

(iii) Sulphide ores change into oxides

$$\underset{\text{Zinc blende}}{2ZnS} + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

Both calcination and roasting are carried out in a special type of furnace called reverberatory furnace.

(3) Extraction of metals from metal oxide :

(A) Extracting Metals Low in the Activity Series

Metals low in the activity series are very unreactive. The oxides of these metals can be reduced to metals by heating alone. For example, cinnabar (HgS) is an ore of mercury. When it is heated in air, it is first converted into mercuric oxide (HgO). Mercuric oxide is then reduced to mercury on further heating.

$$2HgS\ (s) + 3O_2\ (g) \quad 2HgO\ (s) + 2SO_2\ (g)$$

$$2HgO\ (s) \quad 2Hg\ (l) + O_2\ (g)$$

Similarly, copper which is found as Cu_2S in nature can be obtained from its ore by just heating in air.

$$2Cu_2S + 2O_2 (g)\ 2Cu_2O (s) + 2SO_2 (g)$$

$$2Cu_2O + Cu_2S\ 6Cu (s) + SO_2 (g)$$

(B) Extracting Metals in the Middle of the Activity Series

The metals in the middle of the activity series such as iron, zinc, lead, copper, etc., are moderately reactive. These are usually present as sulphides or carbonates in nature. It is easier to obtain a metal from its oxide, as compared to its sulphides and carbonates. Therefore, prior to reduction, the metal sulphides and carbonates must be converted into metal oxides.

The process of obtaining metals from their compounds is known as reduction. Before reduction the ore is subjected to **roasting and calcination.** The sulphide ores are converted into oxides by heating strongly in presence of excess of air. The process is known as **roasting.** The carbonate ores are changed into oxides by heating strongly in absence of excess of air.

Roasting – $2ZnS(s) + 3O_2 (g) \longrightarrow 2\,ZnO(s) + 2\,SO_2 (g)$

Calcination – $ZnCO_3 (s) \longrightarrow ZnO (s) + CO_2 (g)$

(4) Refining or purification of the metal.

(i) Distillation;

(ii) Liquation;

(iii) Poling Electrolytic Refining

METALLURGY IN DETAIL:

CONCENTRATION OF ORE

The process of removal of the gangue particle from the ore is called dressing (or) concentration (or) benefaction.

It can be classified into various types, depending upon the nature of impurities

(I) Hand picking;

(II) Hydraulic washing (or) gravity separation (or) levigation

(III) Magnetic separation ;
(IV) Froth floatation;
(V) Leaching (or) chemical separation

(I) Hand picking: If ore particles and impurities (gangue) are different in size & shape, hand picking process can be used to separate it.

For example, Haematite ore is purified by this method

(II) Hydraulic washing (or) gravity separation (or) levigation: This method is based on the difference in specific gravity of the ore & gangue particle.

Gangue particles are lighter than the ore particles.

In this method the ore is mixed with water (or) washed with an upward stream of running water, the lighter gangue particles are washed leaving behind the ore particles.

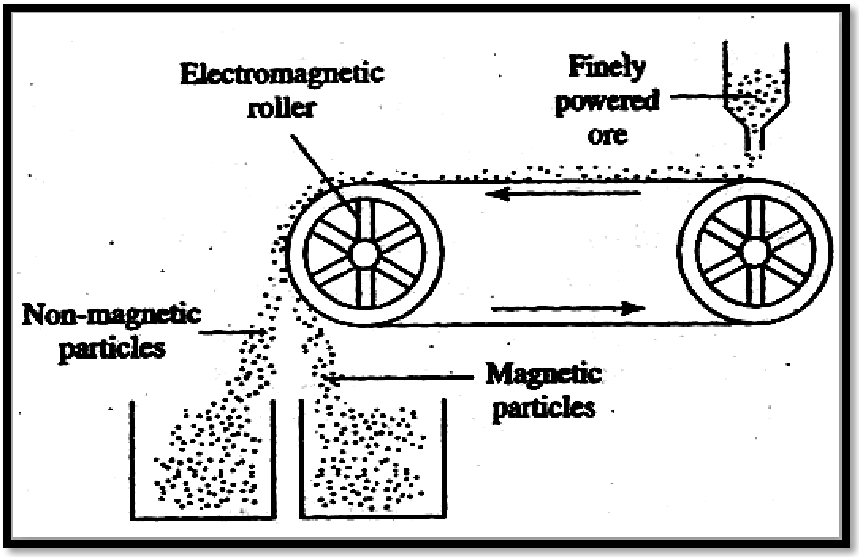
For example, this method is used for concentration of the oxide ores of Iron (Hematite), Tin (Tinstone), Au & Ag etc.

(III) Magnetic separation : If ore or gangue particles are having magnetic nature, then it is concentrated by this method.

This method is based on the difference in the magnetic properties of the ore and the gangue. This method can be applied when either the ore is magnetic or the impurities are magnetic. The other component should be non-magnetic.

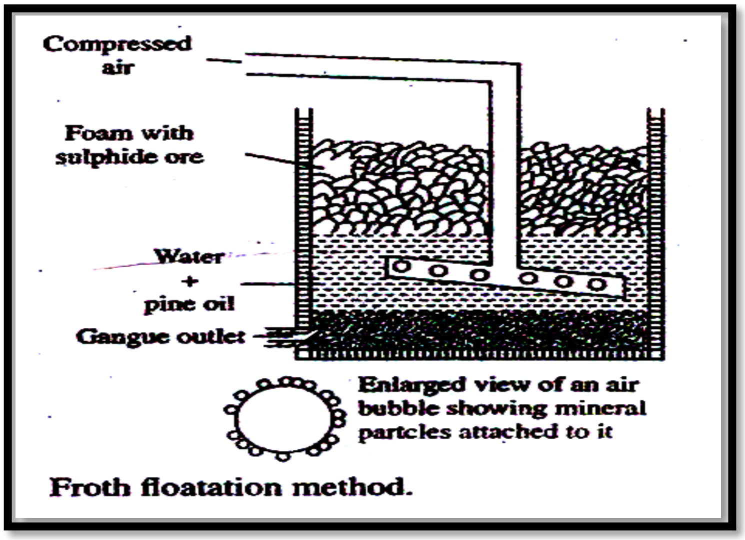
Ex. Magnetite, an ore of iron is enriched by applying this method. Here, the ore particle are attracted by the magnetic roller. Similarly, tungstates of iron (impurity) are removed from tin stone (an ore of tin) by this method.

In this method, the powdered, impure ore is dropped over a travelling belt moving around two rollers, one of which has a magnet attached to it. As the impure ore particles roll over the left, the magnetic particles are attracted by the magnetic roller & ore collected just below the magnetic roller, But the non-magnetic particle fall away from the magnetic rollers.



(Fig. Magnetic Separation)

(IV) **Froth flotation process :** It is used for separating impurities from the sulfide ores. Copper pyrities ($CuFeS_2$), galena (PbS) & zinc blende (ZnS) are concentrated by using this method.This process based upon the fact that the surface of sulphide ore is wetted by oils, while gange is wetted by water.



This method is generally applied for the concentration of the sulphide ores. The finely crushed ore is taken in a tank filled with water and a little (about 1%) pine oil or mineral oil is added.

A small quantity of a substance such as soap (called collector) is also added. The whole mass is vigorously stirred by passing compressed air (figure) through it when froth is produced.

The ore particles get preferentially wetted by the oil while the gangue particles are wetted by the water. The ore thus rises to the top along with the froth and can be skimmed off easily. The gangue particles are left behind. The froth containing ore particles is washed with water to recover the concentrated ore. This method is used to concentrate the sulphide ores of copper, lead and zinc.

(V) Leaching (or) chemical separation

This method is based on difference between the chemical properties of the ore and the gangue.The process consists of treatment of the powdered ore with a suitable reagent (such as acids, base (or) other reagents) which can Selectively dissolve, the ore but not the impurities.

Ex: Baeyer's process: pure aluminium oxide is obtained from the Bauxite ore (containing Fe_2O_3 & silicates) by leaching. The powdered ore is treated with concentrated solution of NaOH (base) where Al_2O_3 dissolves in the form of sodium aluminate leaving behind the impurities which can be separated by filtration.

$$Al_2O_3\ (s) + 2NaOH\ (aq) + H_2O\ (l) \longrightarrow 2NaAlO_2\ (aq) + H_2O\ (l)$$

sodium aluminate

Sodium aluminate on dilution (or) by neutralisation with CO_2 gives Aluminium hydroxide (ppt).

$$2NaAlO_2\ (aq) + 2H_2O\ (l)\quad Al(OH)_3\ (s)\downarrow + NaOH\ (aq)$$

white ppt

$Al(OH)_3$ on heating gives pure alumina.

$$2Al(OH)_3\quad Al_2O_3 + 3H_2O$$

Leaching is also used for extracting metals like Au & Ag by converting these metals (or) their ores into soluble complexes with the help of NaCN (or) KCN (Dilute solution)

$$Ag_2S + NaCN \longrightarrow 2Na[Ag(CN)_2] + Na_2S$$

sodium dicyano argentate (I)
(soluble complex)

CHEMICAL REDUCTION

(I) Before reduction the ore is subjected to roasting and calcination (as discussed earlier)

It is carried by using carbon (or) hydrogen (or) aluminium as reducing agents.

(A) Carbon as a reducing agent (i.e. smelting)

The reduction of metal oxides with carbon is known as smelting. The roasted (or) calcined ore mixed with carbon (in the form of coal, coke (or) charcoal) and heated to a temperature above its melting point in a furnace.

$$MO + C \longrightarrow M + CO$$

Ex: $ZnO\ (s) + C\ (s) \longrightarrow Zn\ (s) + CO\ (g) \uparrow$

$SnO_2\ (s) + 2C\ (s)\ \ Sn + 2CO\ (g) \uparrow$

Cassiterite

The carbon monoxide produced can also bring about the reduction of metal oxide to free metal.

Ex: $ZnO + CO \longrightarrow Zn + CO_2\uparrow$

$Fe_2O_3 + CO \longrightarrow 2FeO + CO_2\uparrow$

$FeO + CO \longrightarrow Fe + CO_2\uparrow$

Important application for carbon reduction is to extract the Iron which is carried out in a blast furnace.

(B) Hydrogen as a reducing agent

Metals like W, Mo ⟶ Cannot be reduced by carbon

They can be reduced by passing a current of hydrogen

$$WO_3 + 3H_2 \longrightarrow W + 3H_2O$$

Hydrogen is rarely used as reducing agent, because it is highly expensive & also inflammable.

(II) Reduction with aluminium:

Certain metal oxides such as Cr_2O_3 and MnO_2 are not easily reduced with carbon. In such cases, aluminium is used as reducing agent because it is more electropositive than chrominum or manganese. The process of reducing of oxides with aluminium is called Aluminothermy. Some examples are :

$$Cr_2O_3(s) + 2Al(s) \quad Al_2O_3(s) + 2Cr(l)$$

$$3MnO_2(s) + 4Al(s) \quad 2Al_2O_3(s) + 3Mn(l)$$

The reduction of oxides of metals using aluminium as reducing agent is a highly exothermic reaction. The heat produced during the reaction is sufficient to melt the metal. Hence, the metal is produced in the molten state.

Aluminothermic process is sometimes used for welding metals. For example, the reaction Fe_2O_3 with aluminium is used to join railway tracks or cracked machine parts. This reaction known as thermite or thermite reaction.

(III) Reduction with Magnesium

In some cases, the reduction is carried out by alkaline earth elements like magnesium.

(IV) Electrolytic Reduction

The highly electropositive metals (that is the metals occupying higher positions in the reactivity series) such as sodium, calcium, magnesium, etc. cannot be obtained by chemical reduction methods. Such metals are extracted by the electrolytic reduction. In order to obtain these metals their salts are electrolysed in fused state. The commonly used salts are halides. For example, sodium metal is extracted by electrolysis of molten sodium chloride. The chlorine gas is liberated at anode (the positively charged electrode) whereas sodium metal is liberated at cathode (the negatively charged electrode).

$$NaCl \quad Na^+ + Cl^-$$

At anode : $2Cl^- \quad Cl_2 + 2e^-$

At cathode : $2Na^+ + 2e^- \quad 2Na$

The overall reaction may be represented as :

Similarly, aluminium is obtained by electrolytic reduction of aluminium oxide (Al_2O_3) dissolved in molten cryolite (Na_3AlF_6) using graphite electrodes. The reactions taking place are:

At cathode : $Al^{3+} + 3e^- \quad Al(l)$

At anode: $2O^{2-} \quad O_2(g) + 4e^-$

$$2C(s) + O_2(s) \quad 2CO(g)$$

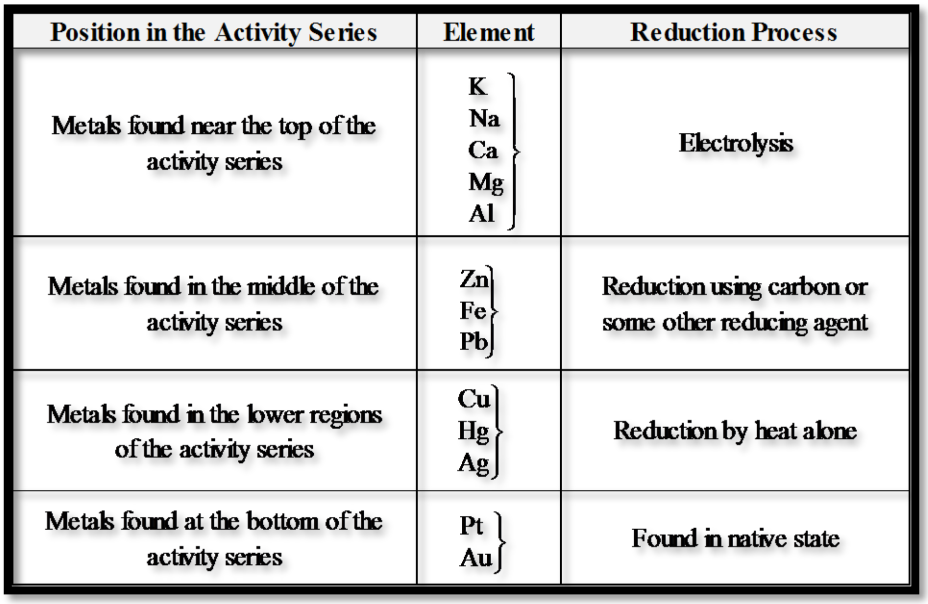
$$2CO(s) + O_2(s) \quad 2CO_2(g)$$

Thus, on the basis of reactivity we can group the metals into the following three categories:

(i) Metals of low reactivity;
(ii) Metals of medium reactivity;
(iii) Metals of high reactivity

Different reduction processes are to be used for obtaining the metals falling in each category. The relation between the reduction process employed and the position of the metals in the activity series is depicted in table.

Table : Position of the metal in the Activity Series and the Related Reduction Process



Position in the Activity Series	Element	Reduction Process
Metals found near the top of the activity series	K Na Ca Mg Al	Electrolysis
Metals found in the middle of the activity series	Zn Fe Pb	Reduction using carbon or some other reducing agent
Metals found in the lower regions of the activity series	Cu Hg Ag	Reduction by heat alone
Metals found at the bottom of the activity series	Pt Au	Found in native state

REFINING (OR) PURIFICATION OF METALS

The process of purifying the crude metal is called refining depends upon nature of the metal & nature of impurities following methods are used

(a) Distillation

(b) Liquation

(c) Oxidation

(d) Electro-refining

(e) Zone refining

(f) Fractional crystallization

(g) Vapour phase refining

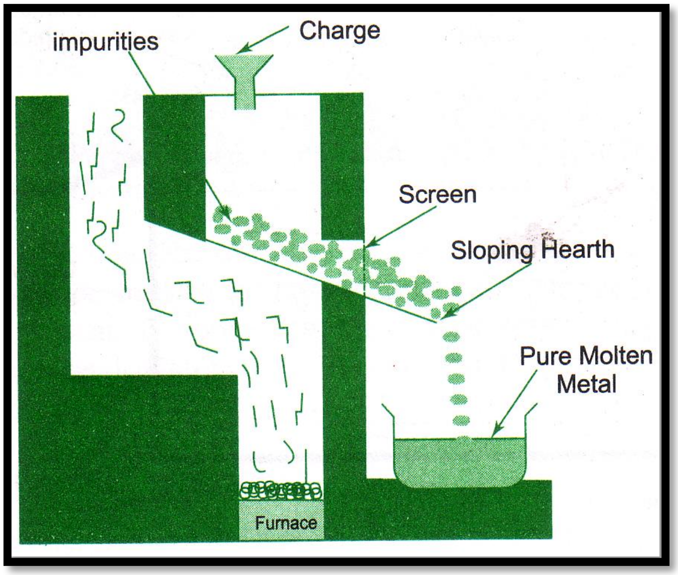
(a) Distillation: Based upon boiling point difference

Distillation is a method of heating impure liquid to its boiling point & cooling the vapours to get the pure liquid.

Low boiling metal like, Zn, Hg, Cd etc can be refined by this method. The impure metal is heated so it is converted into liquid & the pure metal is converted into vapors, leaving the non-volatile impurities in the container, the pure metal vapours on cooling condensed into pure metal.

(b) Liquation process: Based upon melting point difference

When the M.P. of the metal is lower than the impurities, this technique is used.



Low melting point metals such as Bi, Hg, Sn, Pb etc are refined by the process.

The crude metal is heated in an inert atmosphere of carbon monoxide on slopping hearth.

The metal, melts & flows down the hearth, leaving behind the high melting impuries.

(c) Oxidation process: If impurities have greater affinity for oxygen (or) impurities are oxidised more readily than the metal.

Ex: Cu, Ag, Sn, etc.

(i) **Bassemerisation**: This is carried out in a specially designed furnace called Bessemer converter. The impure metal is melted & a hot blast of air is passed through it. Impurities are removed as volatile oxides which escapes out.

(ii) **Cupellation**: This method is used, when the impure metal contain the impurities of other metals, which form volatile oxides. The crude metal is taken in a boat shaped pan and a blast of air is blown into it. The impurities are converted into volatile oxides which escapes.

This process is used for removing the impurities of lead from silver.

(iii) Poling: If crude metal contains impurties of the oxide of the metal itself. The crude metal is melted in a big container and is stirred with green poles of wood. Gaseous hydrocarbons (CH_4, C_2H_6 etc.) released from the green poles reduce the oxides of the metal to the pure state by taking up oxygen.

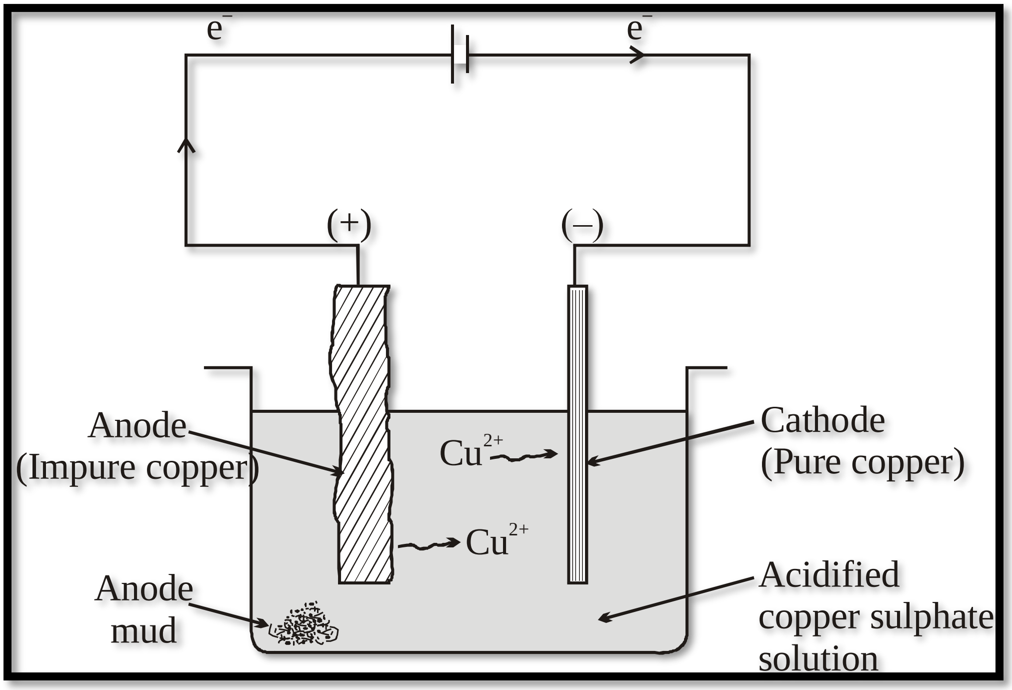
Crude copper (i.e. blister copper) having the impurities

$$3Cu_2O + CH_4 \quad 6Cu + 2H_2O + CO$$

Stannic oxide is also purified by this method.

(d) Electro-refining: Used for Cu, Au, Ag, Pb, Zn & Al. In this method

The impure metal act as Anode & pure metal strip is taken as Cathode (both are same metals), these electrodes are suspended in an electrolyte, (soluble salt of the same metals). On passing electric current, metal ions from the electrolyte are reduced to metal, which is deposited on the cathode in the form of pure metal & an equivalent. Amount of metal from the anode goes into the electrolyte solution.

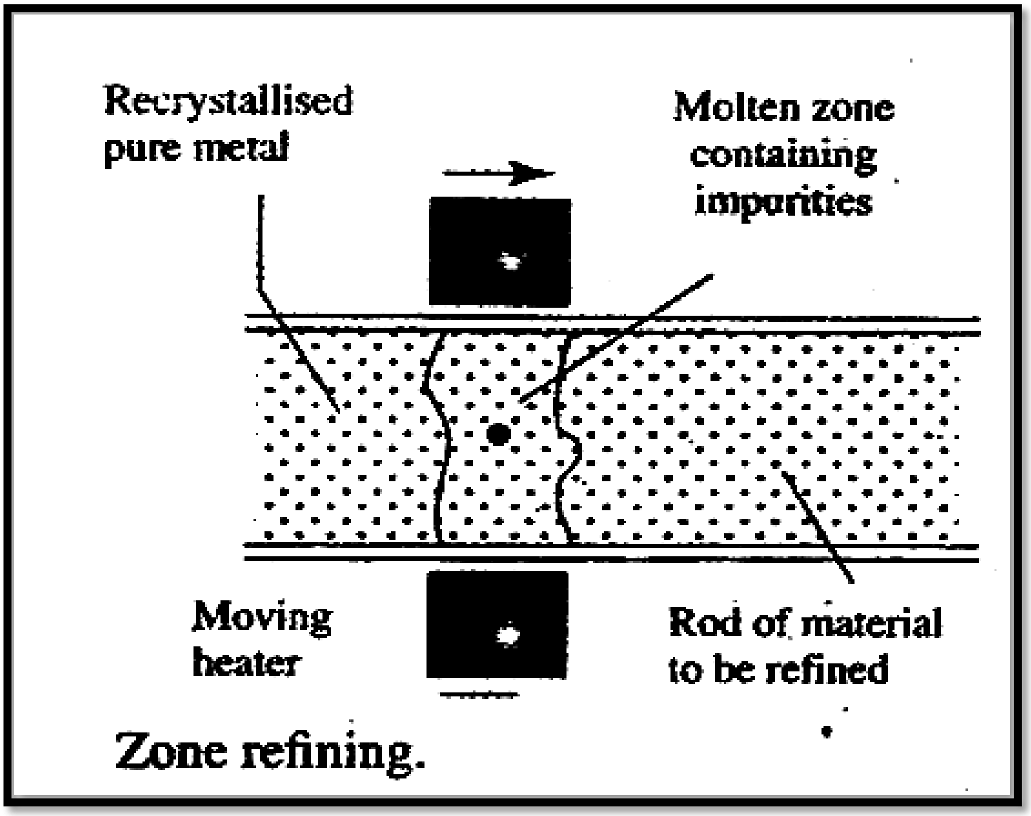


At Anode: $M(\text{Impure}) \rightarrow M^{n+} + ne^-$

At Cathode: $M^{n+} + ne^- \rightarrow M\ (\text{pure})$

Ex: In the electrolysis of copper, metals like Zn remains in the solution as cations. Where as metals such as Au, Ag etc form the Anode mud because its lie lower in activity series with respect to Zn.

(e) Zone refining (or) Fractional distillation: The method is based on the principle that when an impure metal in the molten state is allowed to cool, only the metal crystallises, while the impurities remain in the molten mass (or) melt (Impurities are more soluble).



Zone refining.

This method gives high purity, metals like Ga, In, Si which are used in semi-conductors are purified by this method.

The impure metal is converted into a rod which is heated at one end with a moving circular heater. As the heater is slowly moved along the length of the rod, the pure metal crystallises out of the melt, where as the impurites pass into the adjacent molten zone. This process is repeated number of times till the impurities are driven completely towards one end and the pure metal towards the other end. The entire process is carried out in an inert atmosphere to prevent the oxidation of the metal.

(f) Vapour phase refining: The crude metal is heated with specific reagent at low temperature, so that it is converted into unstable volatile compound, leaving behind the impurities. The unstable voltatile compound is decomposed at a high temperature to give the pure metal.

It is two types:

(i) Mond process: Mond process is used for refining of Nickle. Impure Nickle is heated with carbon monoxide to form volatile Nickle carbonyl, leaving behind the impurities.

$$\text{Ni (Impure)} + \xrightarrow{330\text{-}350K} 4CO\ \ [Ni(CO)_4]\ \ Ni + 4CO$$

vapor pure

(ii) Van-Arkel method: The impure metal heated with Iodine-vapors at high temperature to give vapors of metallic tetra iodide, (unstable). At high temperature these are decomposed to give pure metal. Zirconium (Zr) & Titanium (Ti) are purified by this method

$$\underset{\text{Im pure}}{Ti} + \underset{\text{Vapours}}{2I_2} \xrightarrow[50\text{–}250°C]{500\ k} \underset{\text{Vapours}}{TiI_4} \xrightarrow[1400°C]{1700\ k} \underset{\text{pure metal}}{Ti} + 2I_2$$

ALLOYS:

The homogeneous mixture of two or more metals, or a metal and a nonmetal is called an alloy. For examples, brass is an alloy of copper (Cu) and zinc (Zn). Similarly, steel is mainly an alloy of iron (Fe) and carbon (C). An alloys containing mercury as one of the metals is called an amalgum.

- **Preparation**

(i) Alloys are commonly prepared by melting the desired metals in proper proportions. The melt is allowed to cool and solidify. The solid substance formed is called an alloy.

(ii) By compressing together the various constituents of the alloys under high pressure.

(iv) By simultaneous electro deposition of metals.

Properties of Alloys

Alloys have certain characteristic properties :

(i) They are harder than their constituents but less ductile and malleable.

(ii) They are resistant to corrosion.

(iii) The melting point of an alloy may be higher or lower than any of its constituents.

(v) The properties of an alloy are much more improved and

(vi) pronounced than those of its constituents. For example, aluminum is a light metal and it is not very strong. But Duralumin, an alloy of luminium, is light and very strong.

(vii) The colour of an alloy is different from the metals from which it is formed. For example, both Silver and zinc are almost white but the alloy formed from them are pink in colour.

- **Types of alloys :** There are two types of alloys :

(i) **Ferrous Alloys :**

These are the alloys which contain iron as one of the constituents, such as nickel steel, stainless steel etc.

(ii) **Non-ferrous Alloys :**

These are the alloys which do not contain iron as one of the constituents such as bronze, brass etc.

Few Examples of Alloys

- **Alloys of Gold : T**he purity of gold is expressed in carats. 24 carat gold is pure gold. But pure gold is very soft and, therefore, cannot be used in making ornaments or coins. It is generally alloyed with copper or silver to make it hard and useful. 22 carat gold means that the alloy contains 22 parts of gold in 24 parts of the alloy.
- **Amalgam :** An amalgam is an alloy of mercury and one or more metals. Most of the metals form amalgam with mercury. But iron and Platinum are noticable exceptions. Therefore, amalgams can be stored in iron bottles.

Some of the amalgams are definite intermetallic compounds, such as sodium amalgam (NaHg), magnesium amalgam (MgHg), silver amalgam (Ag_5Hg_8), etc. Amalgams of sodium and aluminium are good reducing agents. Amalgam of silver, tin, Cadmium and copper have been utilized as dental fillings. Amalgams may be solid or liquid.

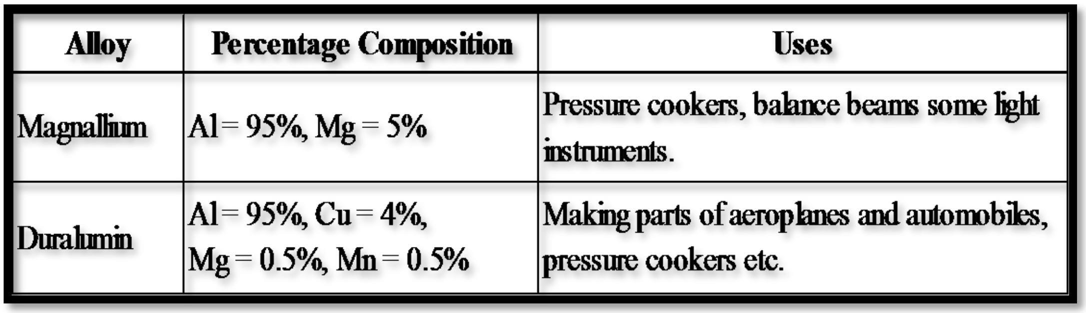
➢ Alloy Steels

Steel : Steel is an alloy of iron and carbon, the carbon content being 0.15–1.7%. Small quantities of other elements such as manganese, silicon, chromium, Molybdenum, cobalt and nickel are added to impart desirable mechanical and chemical properties that cannot be obtained by using carbon alone. Such steels are known as **alloy steels.**

Stainless Steel : Steel that contains over 11–12% of chromium is known as **stainless steel.** Stainless steel does not rust or stain.

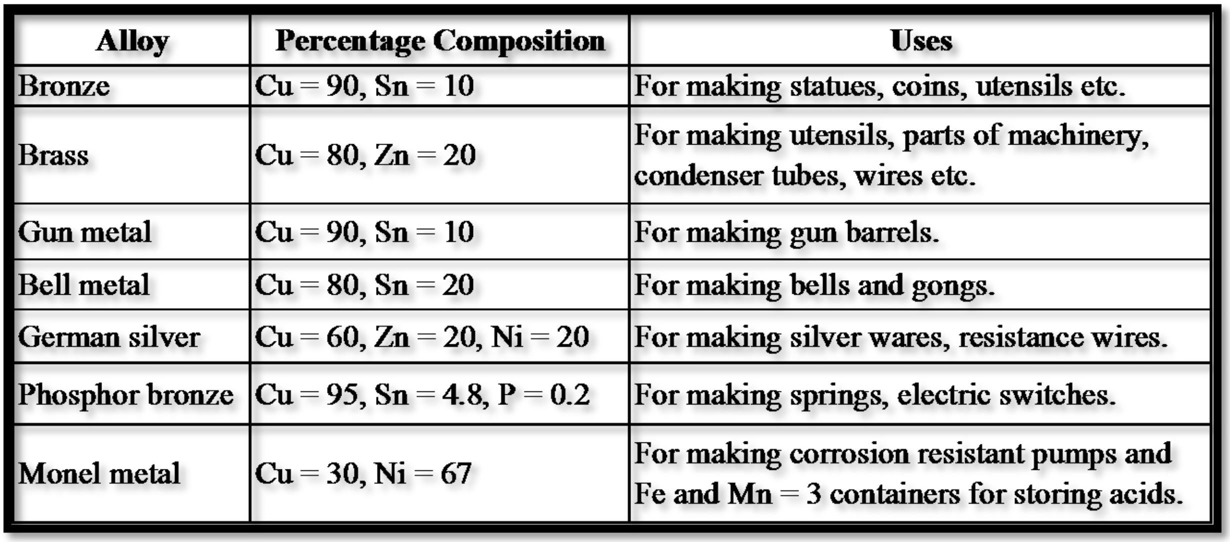
It is, therefore, used to serve a variety of purposes in industrial, chemical and domestic fields. A particularly useful alloy is the steel known as 18–8 which contains Cr (18%), Ni (8%) and C (0.08%). It is now apparent that the ingredient which is instrumental in influencing the properties of steel is carbon.

Alloys of Aluminium



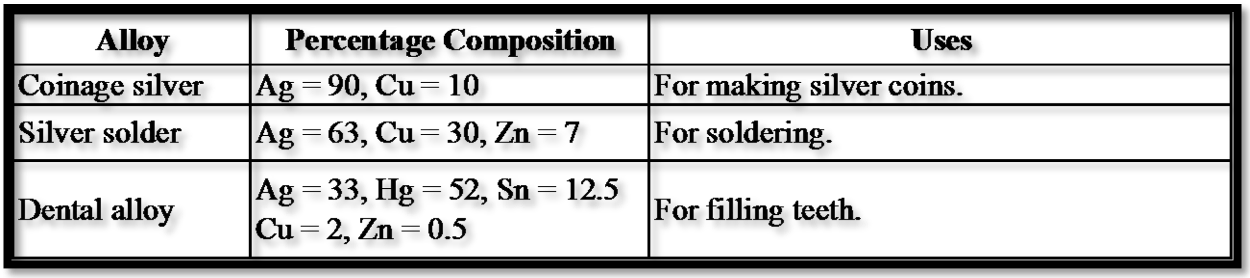
Alloy	Percentage Composition	Uses
Magnallium	Al = 95%, Mg = 5%	Pressure cookers, balance beams some light instruments.
Duralumin	Al = 95%, Cu = 4%, Mg = 0.5%, Mn = 0.5%	Making parts of aeroplanes and automobiles, pressure cookers etc.

Alloys of Copper



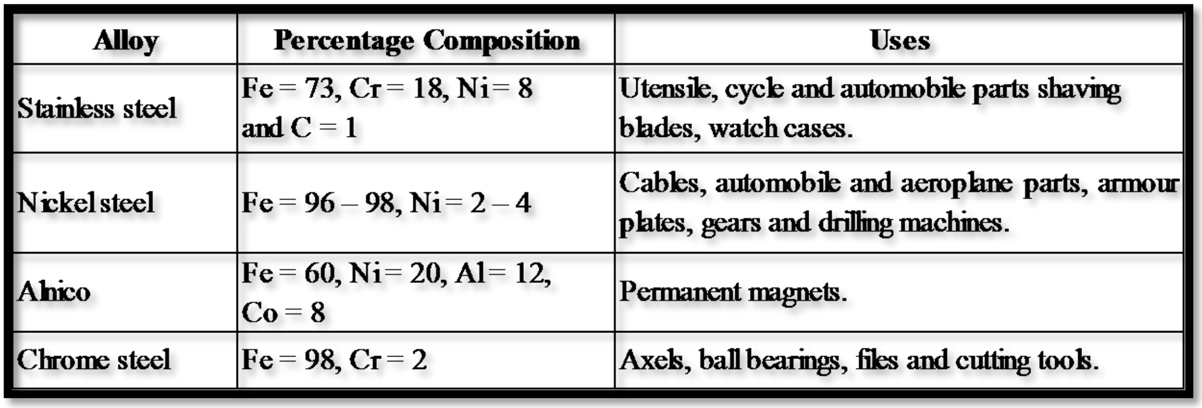
Alloy	Percentage Composition	Uses
Bronze	Cu = 90, Sn = 10	For making statues, coins, utensils etc.
Brass	Cu = 80, Zn = 20	For making utensils, parts of machinery, condenser tubes, wires etc.
Gun metal	Cu = 90, Sn = 10	For making gun barrels.
Bell metal	Cu = 80, Sn = 20	For making bells and gongs.
German silver	Cu = 60, Zn = 20, Ni = 20	For making silver wares, resistance wires.
Phosphor bronze	Cu = 95, Sn = 4.8, P = 0.2	For making springs, electric switches.
Monel metal	Cu = 30, Ni = 67	For making corrosion resistant pumps and Fe and Mn = 3 containers for storing acids.

Alloys of Silver

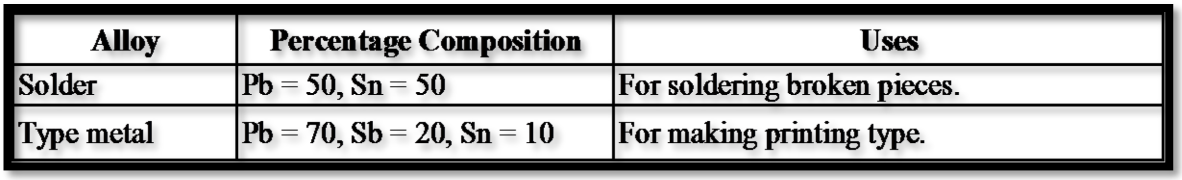


Alloy	Percentage Composition	Uses
Coinage silver	Ag = 90, Cu = 10	For making silver coins.
Silver solder	Ag = 63, Cu = 30, Zn = 7	For soldering.
Dental alloy	Ag = 33, Hg = 52, Sn = 12.5 Cu = 2, Zn = 0.5	For filling teeth.

Alloys of Tin and Lead



Alloy	Percentage Composition	Uses
Stainless steel	Fe = 73, Cr = 18, Ni = 8 and C = 1	Utensile, cycle and automobile parts shaving blades, watch cases.
Nickel steel	Fe = 96 – 98, Ni = 2 – 4	Cables, automobile and aeroplane parts, armour plates, gears and drilling machines.
Alnico	Fe = 60, Ni = 20, Al = 12, Co = 8	Permanent magnets.
Chrome steel	Fe = 98, Cr = 2	Axels, ball bearings, files and cutting tools.



Alloy	Percentage Composition	Uses
Solder	Pb = 50, Sn = 50	For soldering broken pieces.
Type metal	Pb = 70, Sb = 20, Sn = 10	For making printing type.

Alloys of Iron or Alloy Steels

CORROSION OF METALS :

Slow destruction of metals due to chemical reactions on their surface by oxygen, carbon dioxide, moisture, sulphur dioxide, hydrogen sulphide, etc., of the atmosphere, is known as **corrosion of metals**.

Due to corrosion, small holes appear on the surface of the metal and the strength of the metal goes on decreasing. The process of corrosion is caused by the reaction of the metal with oxygen of air or with oxygen dissolved in water.

In corrosion, the metal atoms give up electrons (i.e. they are oxidized) and are converted into ions. $M \rightarrow M^{+} + e$

The ions move from one part of the metal to another more easily in the presence of moisture. This is because moisture provides the medium through which ions can flow.

Factor Determining the Rate of Corrosion

The process of corrosion is speed up in the following circumstances.

1. **The metals are in contact with each other**

   The corrosion of a more electropositive metal is speed up when it is in contact with a less electropositive metal. Two metals form an electrochemical (galvanic) cell in the presence of moisture. Electrons begin to flow from the more electropositive (or more reactive) to the less electropositive (or less reactive) metal. Thus, the more electropositive metal is lost as ions.

   For example, when iron and copper are in contact, electrons flow from iron to copper because iron is more electropositive than copper. Thus, the more reactive metal iron forms ions. The process of iron going away as ions is slower in the absence of copper.

2. Polluting materials in air

The air near industrial units is generally polluted with CO_2, SO_2, H_2S etc. Gases coming out of chimneys contain these gases in abundance. We know that these gases are also responsible for the corrosion of metals. Therefore, the process of corrosion is speed up in presence of these pollutants.

(a) Silver articles become black after some time when exposed to air. This is because it reacts with sulphur in the air to form a coating of silver sulphide.

(b) Copper reacts with moist carbon dioxide in the air and slowly loses its shiny brown surface and gains a green coat. This green substance is basic copper carbonate.

(c) Iron when exposed to moist air for a long time acquires a coating of a brown flaky substance called rust.

Preventive measures

The metallic surface can be coated with appropriate chemicals (ex: bisphenol, oxides etc.)

- Paints are very good corrosion-inhibitors. If they contain red lead zinc chromate or lead chromate. Since these forms the protective coatings.
- Concrete coating & phosphate coating (Fe & Mn-phophates) are very effective against atmospheric corrosion.
- Steel plants & nuclear plants etc are protected by the method of Anodic potential.
- Anodised 'Al' is resistant to corrosion. It is the reason that the bodies of the buses & cars have 'Al' strips around it.
- Glycol in coolant for automobiles is good corrosion inhibitor addition of small quantity of cyanovanador to the thermostats (or) radiators of cars can protect them from corrosion.
- Copper & Brass items can be protected by covering them with p-chlorobenzohydroxamic Acid.

Illustration

What is 24 carat gold? How will you convert it into 18 carat gold?

Solution

24 carat gold is pure gold. It is very soft for which reason it cannot be used for making jewellery. To make it 18 carat, 18 parts of pure gold in alloyed with 6 parts of either silver or copper.

Illustration

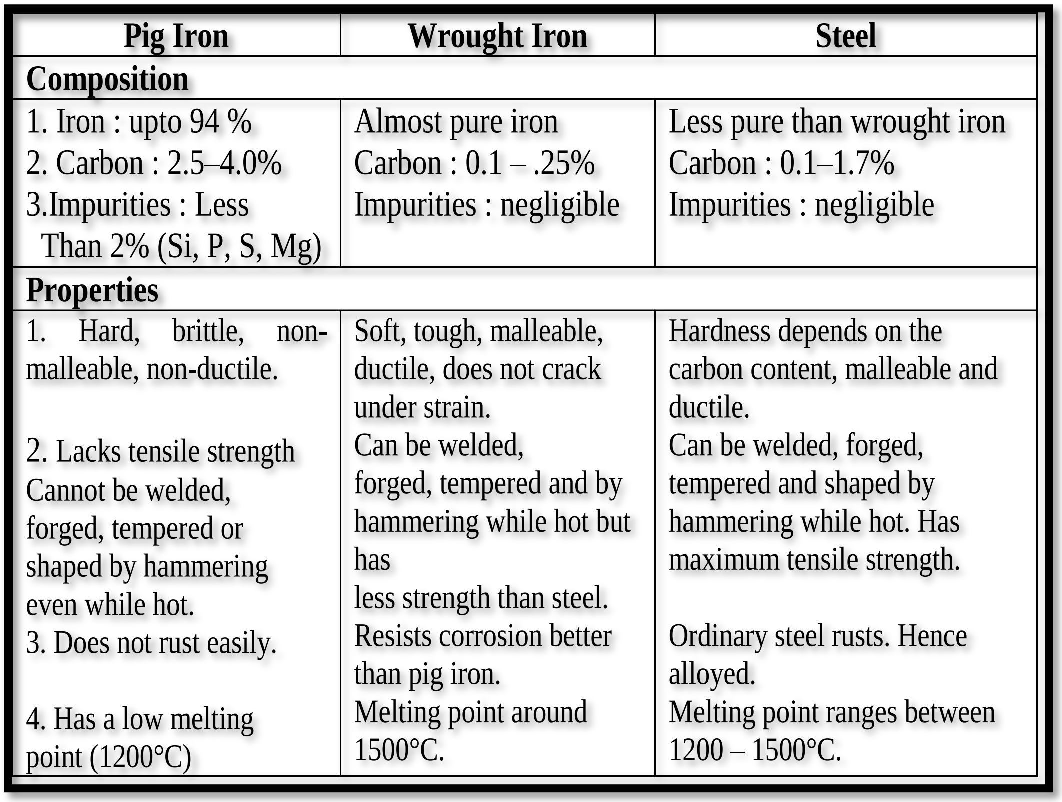
What is rust? Write its chemical formula?

Solution

The deposition of brown, flasy substance on the surface of iron is known as rust. Rust is mainly hydrated iron(III) oxide $Fe_2O_3.xH_2O$, $Fe(OH)_3$

$$Fe + H_2O + O_2 \rightarrow Fe_2O_3.xH_2O + Fe(OH)_3$$

<u>Comparison of Pig Iron, Wrought Iron and Steel</u>



Pig Iron	Wrought Iron	Steel
Composition		
1. Iron : upto 94 % 2. Carbon : 2.5–4.0% 3.Impurities : Less Than 2% (Si, P, S, Mg)	Almost pure iron Carbon : 0.1 – .25% Impurities : negligible	Less pure than wrought iron Carbon : 0.1–1.7% Impurities : negligible
Properties		
1. Hard, brittle, non-malleable, non-ductile. 2. Lacks tensile strength Cannot be welded, forged, tempered or shaped by hammering even while hot. 3. Does not rust easily. 4. Has a low melting point (1200°C)	Soft, tough, malleable, ductile, does not crack under strain. Can be welded, forged, tempered and by hammering while hot but has less strength than steel. Resists corrosion better than pig iron. Melting point around 1500°C.	Hardness depends on the carbon content, malleable and ductile. Can be welded, forged, tempered and shaped by hammering while hot. Has maximum tensile strength. Ordinary steel rusts. Hence alloyed. Melting point ranges between 1200 – 1500°C.

RUSTING

When iron is exposed to moist air, a reddish-brown coating of a mixture of ferric oxide (Fe_2O_3) and ferric hydroxide ($Fe(OH)_3$) is deposited on the surface of the metal. The slow conversion of iron into a mixture of Fe_2O_3 and $Fe(OH)_3$ by water and atmospheric oxygen is known as **rusting.**

Rusting of iron is an oxidation reaction that occurs due to the attack of water and oxygen. It has been found that rusting does not take place in air-free water. It also does not occur in presence of oxygen alone. Both water and oxygen are essential for rusting. Thus, the following conditions are necessary for rusting :

(i) Presence of oxygen or air
(ii) Presence of water or moisture

The process of rusting is continuous. The strength of iron decreases gradually and finally the metal is destroyed completely.

(A) Prevention of Rusting

Iron can be prevented from rusting by the following ways :

1. Rusting of iron can be prevented by covering its surface with paint, grease, enamel, that does not allow air and moisture to come in contact with it and no rusting occurs. This is known as **barrier protection**.
2. Rusting of iron can be prevented by **galvanization**. Zinc metal does not corrode on exposure to air. So zinc coating protect iron from rusting. Zinc itself forms a protective coating of basic zinc carbonate $[Zn(OH)_2.ZnCO_3]$.
3. Rusting can be prevented by coating the surface of iron object with chromium, tin, nickel or aluminium. These metals resist corrosion. Hence, they protect iron from rusting. They may be coated by **electroplating**.
4. Rusting can also be prevented by converting it into an alloy with chromium and nickel. This alloy is called **stainless steel**.
5. Rusting of iron can be prevented by coating it surface with iron (II, III) oxide, Fe_3O_4.

6. Rusting is prevented by **sacrificial protection** in which a more reactive metal is connected to iron objects so that the more reactive metal gets oxidized in preference to the iron object. For example, Mg or Zn being more reactive than Fe are connected to Fe, which are oxidized and said to be scarified. Iron pipes beneath the soil are protected by connecting them to rolls of magnesium (Mg) or Zinc sheets by Sacrificial Protection.

(B) Uses of Iron

1. Iron find wide application in house construction, eg. in the **reinforcement** of roofs and other parts of buildings.
2. Wrought iron and cast iron are largely used in the manufacture of locomotives, railway lines, springs, cubes, etc.
3. Iron has its important therapeutic uses in the treatment of **hypochromic anemias.** The iron deficiency condition impair the formation of haemoglobin and many other functions of red blood cells. Any of iron compounds may be used in therapy and inorganic salts are equally effective for the purpose.
4. All plants, animals and human beings require iron to live. The largest percentage of iron in human beings is present in red blood cells, which are main part of **haemoglobin**. Small quantities of iron are also found in muscles and tissues.
5. Iron is the basic material for thousands of manufactured goods from small pins To mammoth buildings. Iron combines readily with various non-metals such as sulphur and oxygen. Enormous quantities of iron metal is used producing **alloys**, eg. steel (one of the most useful and cheapest metals) is produced by adding a small amount of carbon to iron. Several precious stones, including topaz, turquoise and spinel also contain iron.