CHAPTER 5
METALS AND NON-METALS

NOTES

Metals

- Metals are the elements which form positive ions by losing electron(s). (**Example:** Aluminium becomes Al^{3+} after losing 3 electrons).
- They are placed on the left side of the periodic table.
- Oxides of metals are basic in nature. **Examples:** Iron, Aluminium, Copper Silver, Gold and Tin.

Non-metals

- Non-metals are elements which form negative ions by gaining electron(s).
- They are placed on the right side of the periodic table. Oxides of non-metals are acidic or neutral in nature. Examples: Carbon, Sulphur, Phosphorus, Silicon, Hydrogen, Oxygen and Chlorine.

Metalloids

- The elements which show the properties of both metals and non-metals are called metalloids.
- They form a zig-zag line separating the metals and non-metals in the periodic table.
- Examples: Boron(B), Silicon(Si), Germanium(Ge), Arsenic(As), Antimony(Sb), Tellurium(Te) and Polonium(Po).

Physical properties of metals:

(i) Metals are malleable i.e they can be beaten into sheets.

(ii) Metals are ductile i.e they can be drawn into wires. Gold is the most ductile element.

(iii) Metals are good conductors of heat and electricity. Silver is the best conductor of heat and electricity.

(iv) Metals are lustrous or shiny i.e. they possess metallic lustre.

(v) Metals are generally hard (except sodium and lithium, potassium).

(vi) Metals are solids except mercury.

(vii) They have high melting points but sodium, potassium, gallium and cesium have low melting points.

(viii) They are Sonorous i.e. produced sound on striking a hard surface.

Non-metals:

Physical Properties of Non-Metals:

- They are neither malleable nor ductile, i.e. are brittle in nature.
- Non-metals are poor conductors of heat and electricity.
- They do not have a shining appearance.
- Non-metals are generally soft.
- They exist as solids, liquid and gases (Br is the only non-metal that exists as a liquid).
- They are not sonorous.
- They have low melting and boiling points.

Chemical Properties of Metals and Non-metals:

Formation of oxides:

1. Reaction of metals with oxygen -

$$M + O_2 \longrightarrow 2MO$$
Metal Oxide

Magnesium reacts with oxygen to form magnesium-oxides. Metal oxides are basic in nature.

$$Mg + O_2 \longrightarrow 2MgO$$

Magnesium oxide reacts with water to form an alkali called magnesium hydroxide that turns red litmus blue.

$$MgO + H_2O \longrightarrow Mg(OH)_2$$
Magnesium hydroxide

Metal oxides which show basic as well as acidic behaviours are called amphoteric oxides. **e.g.,** Aluminium oxides react with acids and bases in the following manner

$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$$
$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$
(Sodium meta-aluminate)

Solubility of oxides in water

Some metal oxides are insoluble in water but some of these form alkalis as follows:

$$Na_2O(S) + H_2O \rightarrow 2NaOH(aq)$$
$$K_2O(S) + H_2O \rightarrow 2KOH(aq)$$

Metal oxides react with acids to form salt and water

$$CuO + 2HCl \rightarrow CuCl_2 + H_2O$$
$$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$$

Metal oxides react with both acids as well as bases to produce salts and water is known as **amphoteric oxides.**

Reaction of Non-metal with Oxygen:

(i) Non-metals react with oxygen to form acidic or neutral oxides.

Examples:

a) When sulphur burns in air, it combines with oxygen to form sulphur dioxide

$$S(s) + O_2\ (g) \rightarrow 2SO_2(g)$$
Sulphur dioxide

Sulphur dioxide dissolves in water to form an acid called sulphurous acid

$$SO_2(g) + H_2O\ (l) \rightarrow H_2SO_3$$
Sulphurous acid

b) Carbon reacts with oxygen as follows

$$C(S) + O_2(g) \rightarrow CO_2(g)$$
$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$
(Carbonic acid)

i) Reaction with dilute acids:

Metals react with dilute acids to give salts and hydrogen gas.

E.g.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$
$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$
$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

2. Reaction with water.

Metal react with water to form metal hydroxide (or metal oxide) and hydrogen gas
Potassium and sodium metals react violently even with cold water.

Example:

Sodium reacts with cold water to form sodium hydroxide, hydrogen gas and heat is released.

$$2Na + 2H_2O \rightarrow 2NaOH + H_2 + Heat$$

Potassium reacts with cold water more vigorously forming potassium hydroxide and hydrogen gas with the evolution of heat.

$$2K + 2H_2O \rightarrow 2KOH \quad + H_2 + Heat$$

Magnesium does not react with cold water it reacts slowly with hot water to form magnesium hydroxide and hydrogen gas but reacts rapidly with steam to form magnesium oxide and hydrogen gas

$$Mg(S) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2$$
Hot
$$Mg(S) + H_2O \rightarrow MgO(s) + H_2 + (g)$$
Steam

Aluminium, zinc and red hot iron reacts with steam to form respective oxides and hydrogen.

$$Zn(S) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$$
(steam)
$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$$
(steam)

- Non-metals do not react with dilute acids and water

Occurrence of Metals

- The earth's crust is the major source of metals
- Sea water contains some salts like sodium chloride, magnesium chloride, etc.
- Aluminium is the most abundant metal in the earth's crust.
- Iron is the second most abundant metal while Calcium is the third one.
- Copper and silver are found in nature as their sulphides or oxides.
- Metals like K, Na, Ca, Mg and Al are found in combined state as oxides, sulphides, halides or carbonates.
- Moderately reactive metals like Zn,Fe,Pb are found in earth crust mainly as oxides or carbonates.

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Minerals:

- The natural materials in which the metals or their compounds are found in earth are called minerals.

Ores:

- Ores are those minerals from which metals can be extracted profitably
- For example, Bauxite $(Al_2O_3 2H_2O)$ is the ore of aluminium.
- All ores are minerals but all minerals are not ores.

Extraction of metals (Metallurgy)

The various steps involved in the extraction of the metal from its ores followed by refining is called metallurgy.

The unwanted impurities like sand, rocky material, earthy particles, limestone, mica, etc., are present in an ore are called gangue or matrix.

Steps involved in Metallurgy:

- Concentration or Enrichment of ore
- Extraction of the metals from the concentrated ores (Reduction)
- Refining or purification of impure

Step 1 - Concentration or Enrichment of ore

This is the purification step done by using hydraulic washing, froth floatation process, electromagnetic separation, and leaching.

(a) Hydraulic washing

The crushed and powdered ore is taken in large wooden tanks or spread on tables having grooves on the top. It is then washed in a stream of water and lighter gangue particles are washed away while the heavier ore particles are left behind. Ores of tin and lead are heavy so they are concentrated by this method.

(b) Froth floatation process

This process is used for the concentration of sulphide ores. This process is based on the basis that sulphide ores particles are readily wetted by oil whereas gangue particles are wetted by water. The crushed powdered oil are is wetted with oil and then agitated in a tank containing soapy water. The particles of sulphide ore stick to the froth bubbles and gangue settle at the bottom. The froth on the top is allowed to flow off, and the concentrated ore is recovered .Sulphide ones such as copper pyrites (CuFe S_2), galena (Pbs) zinc blend (ZnS) are concentrated by this method

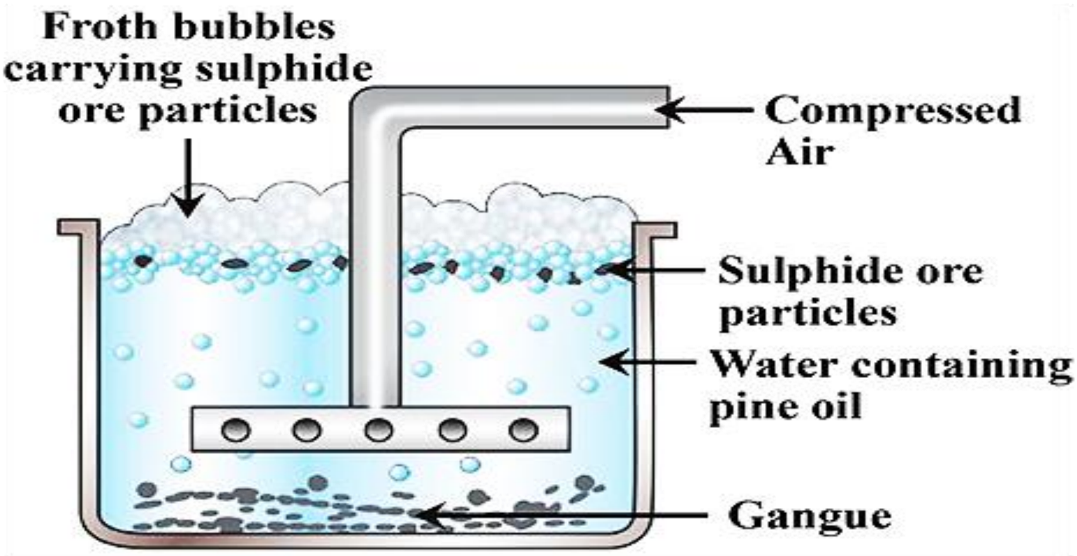

Fig. Apparatus for froth floatation concentration

(c) Electromagnetic separation –

This method is used for the concentration of the ore when either the ore on gangue is magnetic in nature.

A magnetic separator consists of a leather belt moving two rollers. One of the rollers (marked M) has an electromagnet in it. The powdered ore is dropped over the belt on the side of the non-magnetic roller through a hopper. As the ore particles move along over the belt and reach the magnetic roller, the magnetic particles are attracted towards the magnet and form a separate heap. Thus the ore is purified. Some ores like is tinstone, magnetite are separated by this method.

(d) Leaching – This is a chemical method for the concentration of ore .This method depends upon the difference in same chemical Properties of metal compound present in ore and gangue in this process, a particular mineral in the ore is dissolved selectively by using certain acids, bases or other reagents separating it from the gangue.
E.g.- Purification of bauxite ($Al_2O_32H_2O$). Bauxite is treated with hot sodium hydroxide solution.

Sodium hydroxide reacts with aluminium oxide present in bauxite to form of water soluble compound called sodium meta- aluminate.

$$\mathrm{Al_2O_32H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O}$$

The solution is filtered to remove insoluble gangue particles. The filtrate is diluted and agitated to form precipitate of aluminium hydroxide.

$$NaAlO_2 + 2H_2O \rightarrow Al(OH)_3 \downarrow + NaOH$$

The filter, dried and heated strongly to get pure aluminium oxide (alumina)

$$2Al(OH)_3 \xrightarrow{\text{heat}} Al_2O_3 \downarrow + 3H_2O$$

Pure alumina

Step II

Extraction of the metal from the concentrated ore- On the basis of reactivity, metals are classified into – categories. They are highly reactive metals (i) moderately reactive metals and (iii) metals of low reactivity

(a) Extraction of Metals which are low in Activity series

The sulphide and oxides of these low reactive metals can be reduced to metals by heating alone

For example, Cinnabar (HgS) is an ore of mercury

When cinnabar is heated, it is converted into mercuric oxide and on further heating mercuric oxide is reduced to mercury.

(b) Extraction of Metals in the middle of activity series:

These metals are found in the form of sulphides, oxides or carbonates. It is easier to extract the metal from their oxide than sulphides and carbonates. So the sulphide and carbonate ores are converted into corresponding metal oxides.

This is done by the following methods

Calcination: It is the process of heating an ore strongly in limited year.

Example, calamine, a carbonate ore of zinc can be converted to zinc oxide by calcinations.

i) **Roasting:** Roasting is a process in which an ore is strongly heated in the presence of air to convert the sulphide ore into metal oxide and to remove volatile impurities.
ii) **Reduction to the Metal:** In this process the roasted or calcined ore is mixed with suitable quantity of coke (carbon), carbon monoxide or another element which has high affinity for oxygen. Oxides of zinc, iron and lead are reduced to respective metals by heating with coke.
Carbon monoxide formed also act as reducing agent and reduces the metal oxide to metal.

c) Extraction of Metals of High reactivity (K,Na,Ca,Mg):

These metals are obtained by electrolysis of their fused salts and method is electrolytic reduction. Example, electrolysis of fused sodium chloride.

During electrolysis following reactions occur:

$$NaCl\ (s) \xrightarrow{\text{Fusion}} Na^{+}(l) + Cl^{-}\ (l)$$

When sodium chloride melts it splits into sodium ion and chloride ion.

When electricity is passed through the melt sodium ions go to the cathode (negatively charged electrode) and chloride ions move towards the anode (positively charged electrode) and are oxidised to chlorine gas.

Refining of impure Metals:

The metals obtained by various reduction processes still contained impurities and need refinement. The method of refining depends on the nature of the metals and impurities present.

Electrolytic refining is the most widely used method for refining impure metals.

Procedure for refining is as follows:

a) A thick block of impure metal is made the anode
b) A thin strip of the pure metal is made the cathode
c) A water soluble salt (of the metal to be refined) is taken as electrolyte.
When electric current is passed through the solution impure metal from anode dissolves and goes into the electrolytic solution. An equal amount of metal from the solution is deposited on the cathode. In the process the soluble impurities goes into the solution and insoluble impurities settle down below the anode as the anode mud.

Alloys:

- An alloy is a homogenous mixture of one metal with one or more other metal (or non-metal).
- An alloy is prepared by mixing various metals in the molten state and then cooling them.
- An alloy containing mercury as one of the constituent metal is known as amalgam.
- There are about 75 naturally occurring metals and there thousands of different kinds of combinations.
- The properties of alloys are different from the elements of which they are made. For example solder is a low melting alloy of tin and lead but is melting point is lower than that of its constituents.
- Alloys are usually more resistant to corrosion.
  Examples: steel, brass, bronze and duralumin

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