INORGANIC CHEMISTRY

MINERAL : The natural substance in which the metal occurs in its native state or combined state in earth's crust is known as mineral.

Example: $Al_2O_3.2H_2O$ (Bauxite) is a mineral of Al.

ORE : The mineral from which metals can be extracted conveniently and economically is called ore For example: Bauxite ($Al_2O_3.2H_2O$) is also the ore of Al because it can be extracted easily and profitably.

Note:- All ores are minerals, but all minerals are not ores.

Distinction between Minerals and Ores

ORES	MINERALS
1.The minerals from which metals can be extracted conveniently and economically	1. The natural occurring substances in which metals present in native state or combined state.
2. All ores are minerals.	2. All minerals are not ores.
3. Extraction of metals from ores is convenient and profitable.	3. Extraction of metals from minerals is difficult and non-profitable.
4. Example: Bauxite ($Al_2O_3.2H_2O$) is an ore of Aluminum.	4. Example: Clay ($Al_2O_3.2SiO_2.2H_2O$) is a mineral of Aluminum.

EXTRACTION OF METALS: METALLURGY

The process of extraction of metals from their ores is called metallurgy.

The general methods of extraction of metals are:

1. **Crushing and Grinding of ore**
2. **Concentration of ore or Ore Dressing**
3. **Oxidation**
4. **Reduction**
5. **Refining**

1. CRUSHING AND GRINDING OF ORE

The ores obtained from mines are in the form of big lumps. These are first crushed into small pieces with the help of jaw crusher or grinder. Then these pieces are converted to fine powder form with the help of ball mill or stamp mill. The process is called pulverization.

2. CONCENTRATION

The process of removal of unwanted impurities (gangue or matrix) from the ore is called concentration or ore dressing. The method of concentration to be followed depends upon the nature of the impurities present in the ore. The following methods are adopted for the concentration of ores.

A. GRAVITY SEPARATION METHOD

This method is used when the ore particles are heavier than earthy or rockey gangue particles. This method is commonly used for oxide ores. In this method the powdered ore is fed into a stream of running water so that the lighter impurities are washed away and heavier ore particles are left behind. This method is used only on a small scale.

B. MAGNETIC SEPARATION METHOD

The ores which are attracted by a magnet can be separated from the non-magnetic impurities with the help of magnetic separation method. This method applicable for concentration of magnetic ores like haematite(Fe_2O_3) or Magnetite(Fe_3O_4), pyrolusite(MnO_2) etc. The powdered ore is dropped over the moving belt at one end, so that the magnetic ores are attracted by magnetic roller at other end leaving the non-magnetic materials.

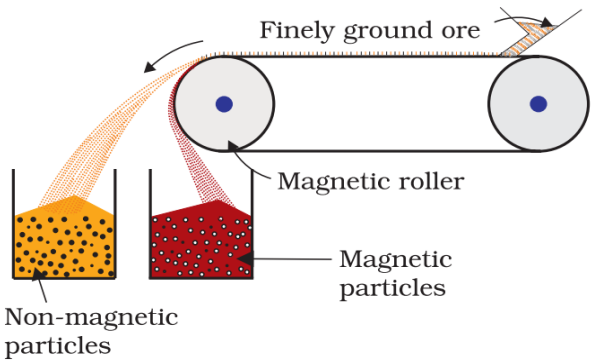

Fig. Magnetic Separation Method

C. FROTH FLOATATION METHOD

This method is applicable for the concentration of sulphide ores like zinc blende (ZnS), copper pyrites ($CuFeS_2$),galena (PbS) etc. In this method, the powdered ore is mixed with water containing small

quantities of pine oil or eucalyptus oil in a large tank. The water is agitated by blowing air violently. So that the froth (or foam) containing lighter sulphide ore particles comes above of the tank. In this way sulphide ores from the main ore are being separated. This process of concentration ore is called froth floatation method.

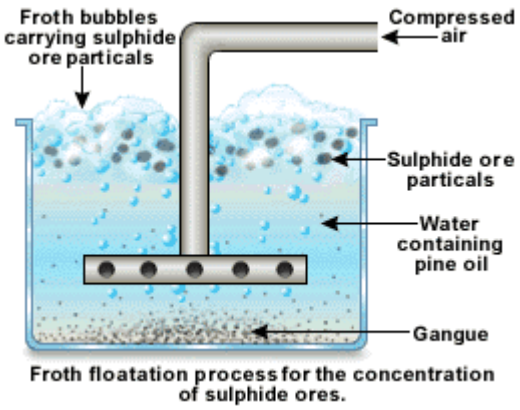

Fig. Froth Floatation Method

D. LEACHING

This is a chemical method in which the impure ore is treated with a suitable solvent which dissolves the ore leaving behind the impurities. The solution is filtered to separate impurities. The filtrate obtained is further treated with another solvent to get precipitate of ores. Then the precipitate is strongly heated to get its pure form.

For example: Impure bauxite ore can be purified by leaching process.

The impure bauxite ore is treated with dil. NaOH solution which dissolves bauxite to form soluble Sodium Meta-aluminate.

$Al_2O_3.2H_2O + 2NaOH \longrightarrow 2NaAlO_2 + 3H_2O$

(Impure alumina) (soluble Sodium Metaaluminate)

The solution of sodium metaaluminate is filtered to remove the impurities. The solution obtained is diluted with excess distilled water when a precipitate of $Al(OH)_3$ is formed.

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

(Precipitate)

The precipitate obtained is dried and heated strongly to get pure alumina.

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

(pure alumina)

3. OXIDATION

In this process the concentrated ore is converted to its oxide form. The concentrated ore can be converted into its oxide form by the following two methods.

A. CALCINATION

The process of heating the ore strongly either in a limited supply air or in the absence of air is called calcination. The following changes occur during the calcination process.

i) It removes moisture.

$Al_2O_3.2H_2O \rightarrow Al_2O_3 + 2H_2O$

ii) It removes volatile impurities like S, P, As, Sb, etc.

$S + O2 \rightarrow SO_2\uparrow$

$2P + 5O_2 \rightarrow 2P_2O_5\uparrow$

iii) It oxidizes oxidizable substances

$4FeO + O2 \rightarrow 2Fe_2O_3$

iv) It decomposes carbonates of alkali and alkaline earth metals into oxides.

$CaCO_3 \rightarrow CaO + CO_2\uparrow$

B. ROASTING

The process of heating the ore strongly below its melting point is called roasting**.** The process of roasting is carried out in a reverberatory furnace.

The following changes occur during the roasting process.

i) It removes moisture.

$Al_2O_3.2H2O \rightarrow Al_2O_3 + 2H_2O \uparrow$

ii) It removes volatile impurities like S, P, As, Sb, etc.

$S + O_2 \rightarrow SO_2 \uparrow$

iii) It oxidizes oxidizable substances.

$4FeO + O_2 \rightarrow Fe_2O_3$

iv) It decomposes carbonates into oxides.

$CaCO_3 \rightarrow CaO + CO_2 \uparrow$

v) It makes the ore porous.

4. REDUCTION

In this process the concentrated ore is converted to its oxide form.

In this step of metallurgical operation the roasted ores are reduced to the metal oxides into the respective metals. One of the methods of reduction is Smelting.

SMELTING

The process of heating a roasted ore strongly above its melting point with a suitable quantity of coke or charcoal is called smelting. During the process of smelting, metal oxides are reduced into their respective metals. Less electropositive metals such as Zn, Fe, Pb,Cu, Mg etc. are converted into their oxides on rudcution with coke.

$ZnO + C \rightarrow Zn + CO$

$PbO + C \rightarrow Pb + CO$

$Fe_2O_3 + C \rightarrow Fe + 3CO$

$Fe_2O_3 + CO \rightarrow Fe + 3CO_2$

During the process of smelting, an additional substance called flux is added which combines with the impurities to form fusible substance called slag.

Impurity + flux → slag

Flux : The substance added during the process of smelting to convert the gangue or matrix into fusible substance is called flux. Examples: SiO_2(acidic), P_2O_5 (acidic), CaO(basic), MgO(basic) etc.

Slag: Slag is the fusible mass obtained during the process of smelting when flux combines with impurities".

The nature of the flux to be added depends upon the nature of the impurity present. For acidic impurities basic flux while for basic impurities acidic flux are used.

SiO_2	+	CaO	→	$CaSiO_3$
(Acidic impurity)		(Basic flux)		(Slag)

FeO	+	SiO_2	→	$FeSiO_3$
(Acidic impurity)		(Basic flux)		(Slag)

5. REFINING

The metal obtained after reduction still contains some impurities. The process of removal of impurities from crude

metal is called refining. The method of refining to be followed depends upon the nature of the metal and the impurity present in it.

A. DISTILLATION METHOD

This method of refining is suitable for volatile metals like Hg, Zn, Pb etc. contaminated with non-volatile impurities. The impure metal is heated in a distillation flask attached with a water condenser.On heating the volatile metal gets evaporated and condensed and that is collected in a separate container while the non- volatile impurities left at the bottom of the distillation flask.

B. LIQUATION METHOD

This method is suitable for refining the easily fusible metals containing non-fusible impurities. Normally metals such as Sn, Pb etc. are refined by this method. In this method of refining the impure metal is taken in a sloping hearth and is heated from the bottom. The metal liquefies and flows down the sloping hearth leaving the impurities on the hearth.

C. ELECTRO REFINING

This method is employed to refine the less electro positive metals such as Zn, Pb, Al, Cu etc. The impure metal is used as anode while a pure metal (same metal) is taken as cathode. Both the electrodes are dipped in a suitable aqueous solution of the concerned metal. During the process of electrolysis, the impure metal dissolves in its aqueous solution and metal ions which get deposited on the surface of cathode.

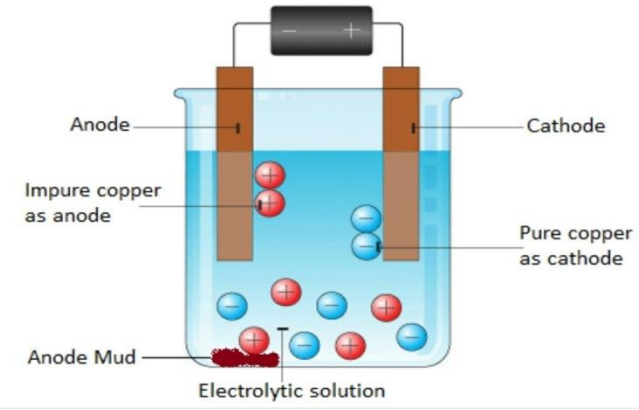

Fig. Electrorefining of Copper Metal

ALLOY

The material obtained by melting together metals or metals with non-metals or metals with metalloids is called an alloy. Or, in other words, an alloy is a combination of two or more different elements. Alloys containing mercury as one of the constituent are called amalgams.

Classification of Alloys: Alloys can broadly be classified into two categories.

A. Ferro alloys

B. Non-Ferro alloys

A. Ferro alloys: The alloy containing iron(Fe) as the main constituent is called a ferro alloy.

For example: Stainless steel, Manganese steel etc.

B. Non-ferro alloys: The alloy which does not contain iron as the main constituent is called non-ferro alloys. For example: Brass, Bronze, Solder, Gun metal, Bell metal etc.

COMPOSITIONS AND USES OF BRASS, BRONZE, ALNICO AND DURALUMIN

Alloys	Composition	Uses
1. Brass	Cu: 60% – 90% Zn: 40% – 10%	It is used in making: utensils, hard wares, screws, jewellery musical instrument, battery caps tubes, name plates.
2. Bronze	Cu: 80% – 95% Sn: 20% – 5%	Making imitation jewellery, water fittings, statues, medals heavy load bearings, turbine blades, pump valves, coins

3. Alnico	Steel: 50% Ni: 21% Al: 20% Co: 9%	It is used in making permanent magnet.
4. Duralumin	Al: 95% Cu: 4% Mn: 0.5% Mg: 0.5%	It is used in making airships.