METALLURGY

Elements 118 elements

METALS

- Mostly solid (except Hg), brilliant lustre, high density, good conductors of heat and electricity, malleable, ductile, tenacious.
- They usually form basic oxides, are non-volatile, have electropositive nature, form +ve ions by loss of electrons.
- They react with dilute acids to liberate H_2.

NON-METALS

- Non-metals are found in all three states. Non-lusturous, bad conductors of heat and electricity, non-malleable, non-ductile, low density, low tensile strength.
- They usually form acidic oxides, volatile, are electronegative in nature and form -ve ions by gain of electrons.
- They do not react with dilute acids to liberate H_2

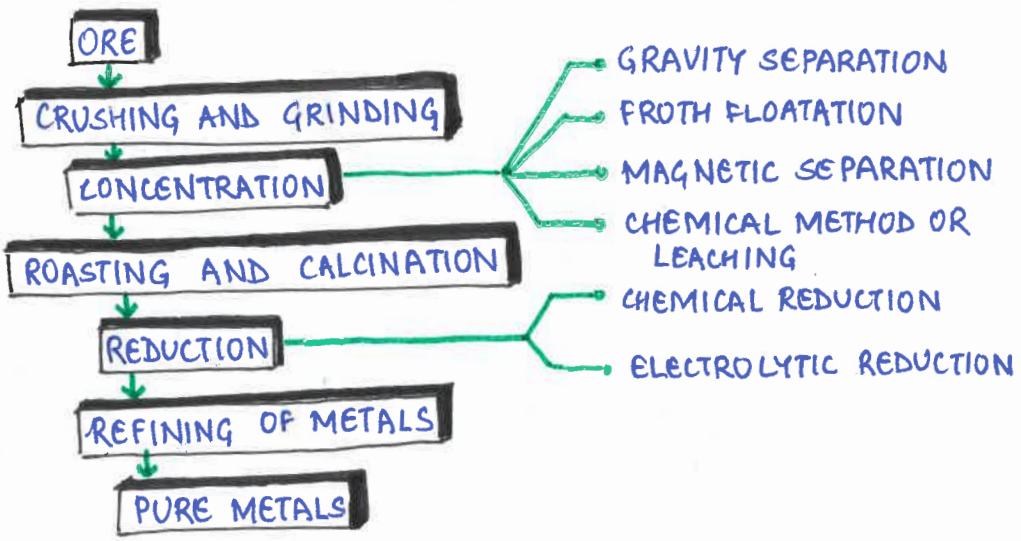
MINERALS: The elementary state or the compounds in the form of which the metals occur in nature

ORE: The mineral from which the metal can be extracted conveniently and economically.

All ores are minerals but all minerals are not ores

METALLURGY: The various steps involved in the extraction of metal from its ores followed by refining of metal.

STAGES INVOLVED IN THE EXTRACTION OF METALS

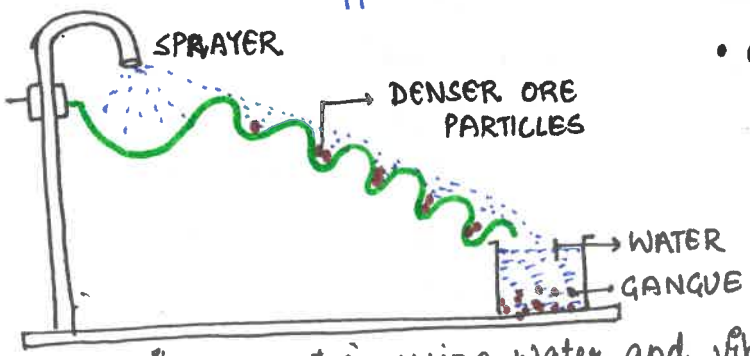


1.) CRUSHING AND GRINDING OF THE ORE: Ores are pulverised ie crushed into small pieces using crushers and ball mills.

2.) CONCENTRATION OF ORE/ENRICHMENT OF ORE: The separation or removal of earthy impurities called 'gangue' from the ore so that concentration of the metal in the ore increases.

HYDRAULIC WASHING OR GRAVITY SEPARATION OR LEVIGATION:

PRINCIPLE: The difference in the densities of the ore and the gangue



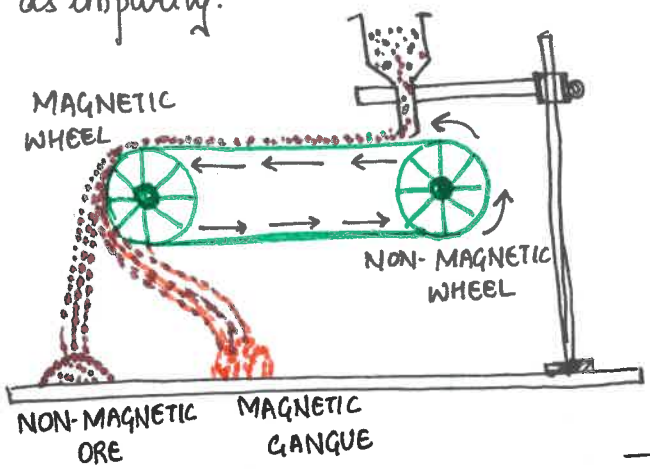
Gravity separation using water and vibrating corrugated table.

- oxides of iron and tin are separated by this method

MAGNETIC SEPARATION:

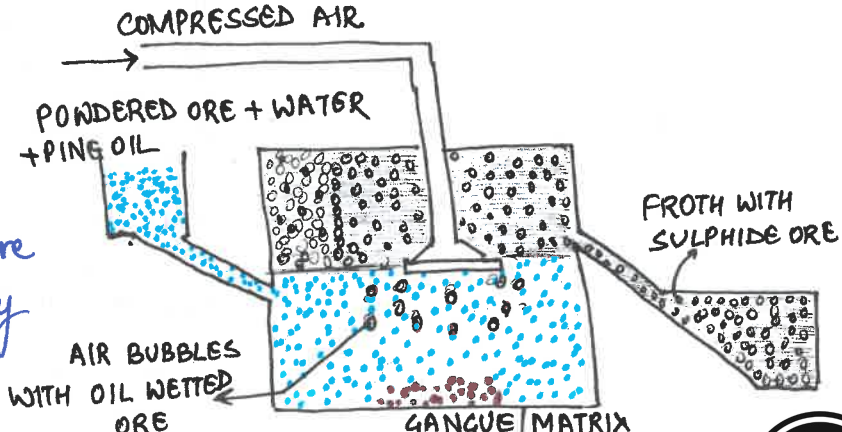
PRINCIPLE: Magnetic properties of the ore.

- used to concentrate tin stone (SnO_2). It contains magnetic oxide of iron (Fe_3O_4) as impurity.



FROTH FLOATATION METHOD:

PRINCIPLE: This process of depends on the preferential wettability of the ore with oil and the gangue particles by water.



- ZnS and PbS are lighter than the impurities present. They are concentrated by this method.

CHEMICAL METHOD OR LEACHING :

ORE + SUITABLE REAGENT (ACID/BASE/SOME OTHER REAGENT) → ORE + IMPURITIES

Removed by filtration.

- used for the concentration of metals like silver, gold, aluminium.

↓ Treated with suitable reagent

ore precipitates.

(II) CONVERSION OF CONCENTRATED ORE TO ITS OXIDE

ROASTING

- Process of heating the ore to a high temperature in presence of air.
- Generally, sulphide ores are roasted

$$2ZnS + 3O_2 \xrightarrow{800-900^\circ C} 2ZnO + 2SO_2\uparrow$$

- Volatile impurities are removed as oxides and the ore becomes porous and more reactive

CALCINATION

- Process of heating the ore in the absence of air to a temperature that is high but insufficient to melt the ore.
- Generally, carbonate and hydrated ores are calcined.

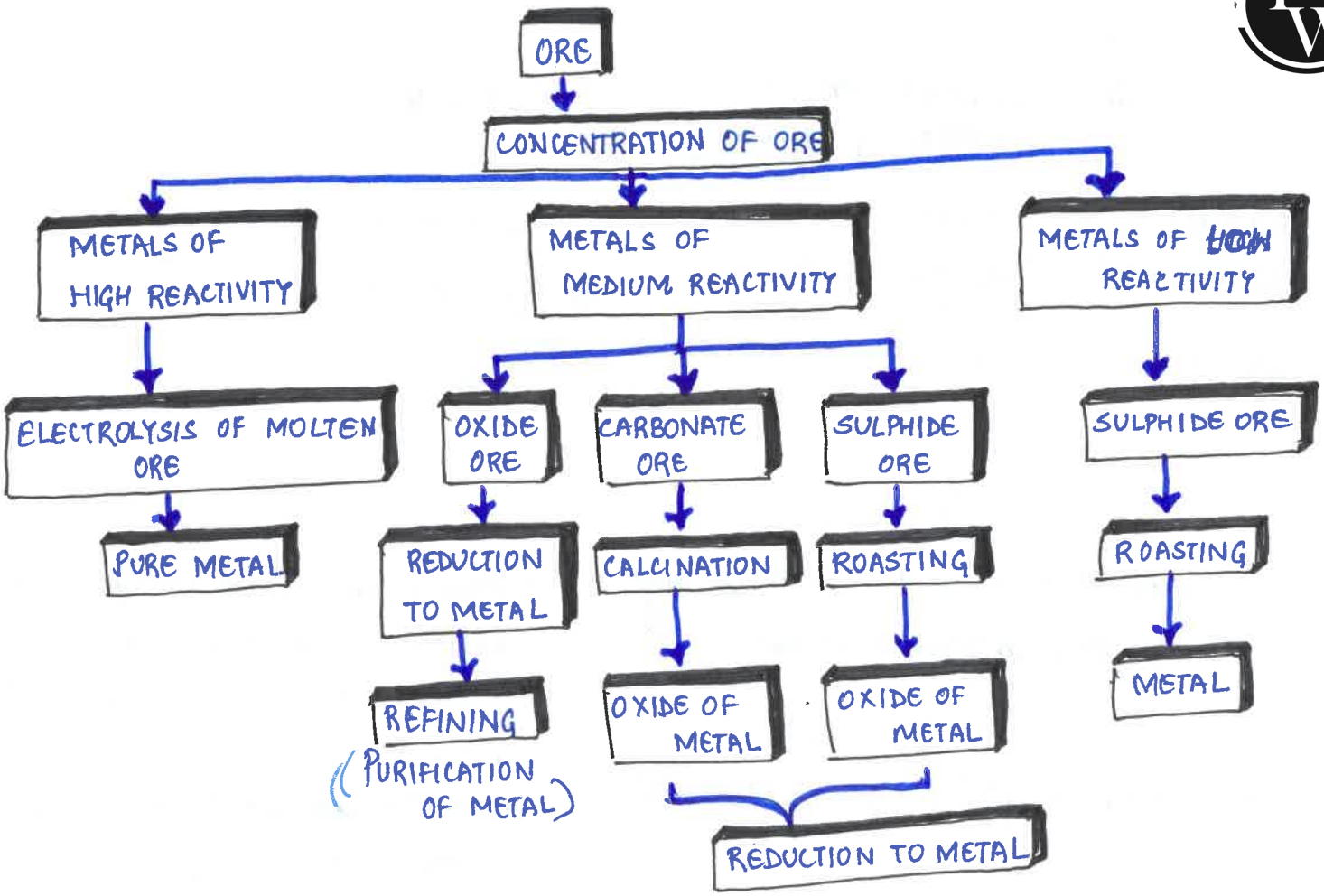
$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2$$

- Moisture and organic impurities are removed and the ore becomes porous and more reactive.

III. REDUCTION OF THE METAL OXIDES TO METALS

After roasting or calcination, the metal oxide is reduced by heating it with reducing agents. The selection of reducing agents depends upon the position of the metal in the reactivity series.

- The arrangement of metals in the decreasing order of their reactivity is called the activity series or reactivity series of the metals.
- Based on their reactivity, metals are categorised as:
  1) Metals of low reactivity
  2) Metals of medium reactivity
  3) Metals of high reactivity



• **REDUCTION OF METAL OXIDE TO METAL:**

Reduction of ZnO, Fe_2O_3 etc. is done by heating with carbon (coke). Reduction of MnO_2, Cr_2O_3 etc. is done by heating with more active metals like Na, K, Al. Reduction of Fe_2O_3 with Al is called thermite reaction. The reduction with Al is called Aluminothermy.

$$Fe_2O_3 + 2Al \longrightarrow 2Fe + Al_2O_3 + \text{heat}.$$

• **REFINING OF THE METAL:**

Refining is the process by which crude metal is purified. The method of purification used depends upon the:

(i) nature of the metal
(ii) nature of the impurities
(iii) purpose for which the metal to be used.

REFINING

- **DISTILLATION**: Volatile metals like Zn, Cd, Hg are refined by distillation
- **LIQUATION**: Easily fusible metals (having low mpts) like lead and tin can be refined by liquation.
- **ELECTROREFINING**: Many metals like Cu, Al, Zn, Ag, Au may be refined using the impure metals as anodes, pure metal strips as cathode and metal salt solution as electrolyte.

EXTRACTION OF ALUMINIUM

- Aluminium: Al, silvery white metal, At. number: 13 At. mass: 27
  Valency: 3 Electronic configuration: 2,8,3
- Most abundant metal in the earth's crust. Discovered by Oersted.

EXTRACTION OF ALUMINIUM

- Purification of bauxite ore

Bayers process

STEP 1: Impure bauxite → sodium meta aluminate

$Al_2O_3.2H_2O + 2NaOH \xrightarrow{150^\circ C} 2NaAlO_2 + 3H_2O$

(Bauxite) (conc) — Sodium meta aluminate

STEP 2: Sodium meta aluminate → aluminium hydroxide

$NaAlO_2 + 2H_2O \xrightarrow{50^\circ C} Al(OH)_3\downarrow + NaOH$

STEP 3: Aluminium hydroxide → Alumina

$2Al(OH)_3 \xrightarrow{1000^\circ C} Al_2O_3\downarrow + 3H_2O$

ELECTROLYTIC REDUCTION OF FUSED ALUMINA

- **Hall-Heroults process**
- ELECTROLYTE: Al_2O_3 : Cryolite : Fluorspar
  1 : 3 : 1
- ELECTRODE:
  CATHODE: Carbon lining
  ANODE: Graphite rods
- TEMPERATURE: 950°C
- PRODUCTS FORMED:
  CATHODE: Pure Al
  ANODE: $O_2(g)$

ROLE OF CRYOLITE:

(i) Mpt of Al_2O_3 gets lowered from 2050°C to 950°C

(ii) Increases electrical conductivity of the mixture.

REFINING OF ALUMINIUM

- **Hoope's electrolytic process**
- It is done in an electrolytic cell which consists of three layers of molten substances differing in specific gravity.
- Molten impure aluminium forms the bottom layer and acts as anode, pure molten aluminium forms the upper layer and acts as cathode. The middle layer is of fluorides.

At Anode:

$Al \longrightarrow Al^{+3} + 3e^-$

At Cathode:

$Al^{+3} + 3e^- \longrightarrow Al$

ORE: BAUXITE $Al_2O_3 \cdot 2H_2O$

CONCENTRATED BY NaOH TO OBTAIN Al_2O_3

$Al_2O_3 \cdot 2H_2O + 2NaOH \xrightarrow{140^\circ C - 150^\circ C} 2NaAlO_2 + 3H_2O$

$NaAlO_2 + 2H_2O \xrightarrow{50^\circ C} NaOH + Al(OH)_3 \downarrow$

$2Al(OH)_3 \xrightarrow{1000^\circ C} Al_2O_3 + 3H_2O$

ELECTROLYTIC REDUCTION OF ALUMINA

Electrolyte: Alumina, Cryolite, fluorspar (1:3:1)

Cathode : $4Al^{+3} + 12e^- \longrightarrow 4Al$

Anode : $6O^{-2} \longrightarrow 3O_2 + 12e^-$

$C + O_2 \longrightarrow CO_2$

PURIFICATION BY ELECTROLYSIS

CATHODE : $Al^{+3} + 3e^- \longrightarrow Al$

ANODE : $Al \longrightarrow Al^{+3} + 3e^-$

ALLOYS

An alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

- PURPOSE OF MAKING ALLOYS: The purpose of an alloy is to improve the specific usefulness of the primary component and not to adulterate or degrade it.

- REASONS FOR ALLOYING :
  - To modify appearance and colour :
  - To modify chemical activity
  - To modify casting ability
  - To lower the melting point
  - To increase the hardness and tensile strength
  - To increase resistance to electricity