CHAPTER - 6

GENERAL PRINCIPLES AND PROCESSES OF ISOLATION OF ELEMENT

→ **Metallurgy**
The scientific and technological processes used for isolation of metals from their ores.

→ **Minerals**
The natural chemical form in which metals exist in nature is called a Minerals.

→ **Ores**
Those minerals from which the metal can be extracted conveniently and profitably are called Ores.

- Some common Ores :

1)	Aluminium	Bauxite	$Al_2O_3 \cdot xH_2O$
2)	Iron	Halmetite	Fe_2O_3
		Magnetite	Fe_3O_4
3)	Copper	Cuprite	Cu_2O
		Copper glance	Cu_2S
4)	Zinc	Zinc blende	ZnS
		Calamine	$ZnCO_3$

★ STEP INVOLVED IN METALLURGY

1) Concentration of Ores

The removal of unrequired earthly matter (gangue particles) from proceed ore is known as concentration of Ores.

a) MEGNETIC SEPARATION

- This process is used for the removal of gangue particles from iron ores like haematite, magnetite, etc.

b) HYDRAULIC WASHING

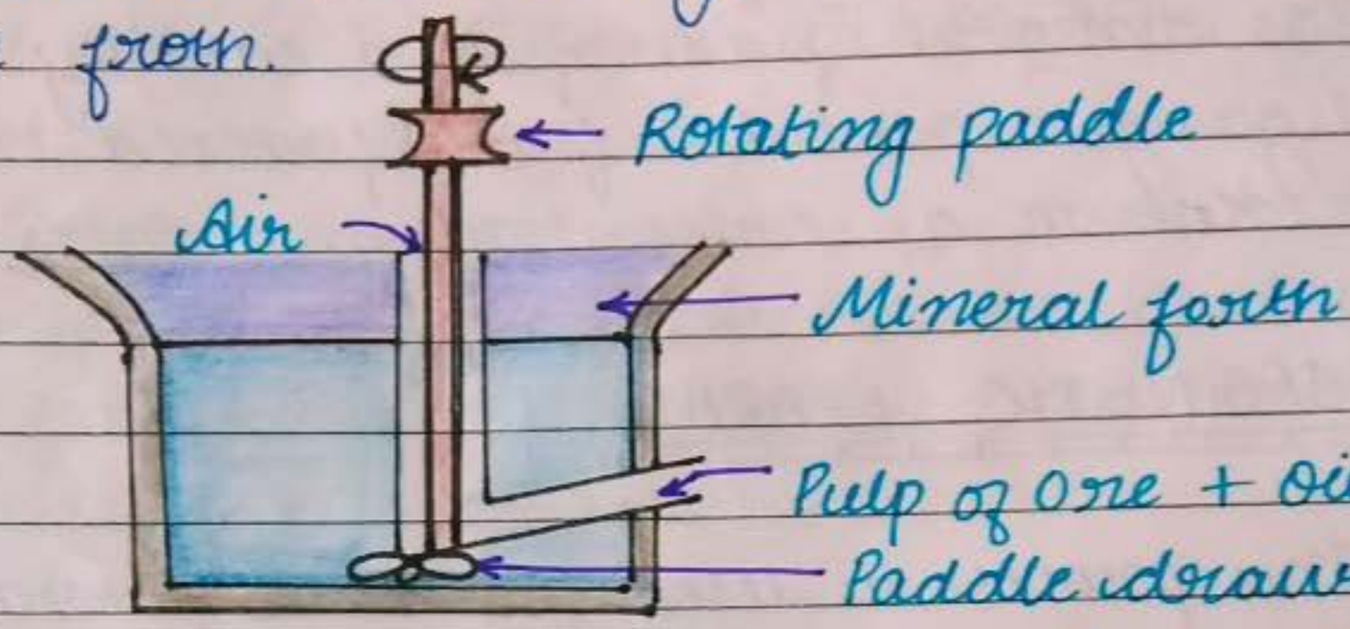
- It is a kind of gravity separation in which powedered ore particle are made to fall on a groovy slopy surface and they remain on grove being heavier whereas lighter gangue particles flow down with water.

★★ Principle : Gravity separation

c) FROTH FLOATATION PROCESS

- This Process is used for the conc. of sulphide Ores.

Collectors: Example → Pine oil
These enhance the non-wetibility of ore particle and bring them on the surface with froth.



Froth stabilizer (Aniline) → Its function is to stabilize the froth.

Depressant: Example → NaCl for separation of two sulphide ores PbS and ZnS.
Role of depressant is to enhance the non-wetibility of PbS.

★★ Principle: Ore particles are wetted by oil where as gangue particle are wetted by water.

d) LEACHING

• Leaching is often used if the ore is soluble in some suitable solvent.

→ Leaching of Alumina from Bauxite

Bauxite ore consist of Impurities of iron, Ti, Si, on adding aq. NaOH to powdered ore, sodium aluminate and Sodium Silicate leached out. SiO_2, TiO_2, iron oxide

$$Al_2O_3 + NaOH + H_2O \xrightarrow{473-523\ K} Na[Al(OH)_4]$$

powder ore — soluble — 35-36 bar

When sodium aluminate and sodium silicate is treated with CO_2 alumina gets precipitated leaving sodium silicate in , alumina is filtered off.

$$Na[Al(OH)_4] + CO_2 \longrightarrow Al_2O_3 \cdot xH_2O + NaHCO_3$$

→ Examples : Au / Ag

Precious metals like Au and Ag, they all leached out by treating with dilute solution of NaCl / KCl bling presence of O_2.

$$Au + CN^- + H_2O + O_2 \longrightarrow [Au(CN)_2]^-$$

2) Extraction of Crude Metal from Concentrated Ore.

- Metals are extracted by converting them into suitable form for the reduction to metal.

- Sulphide Ores are converted to oxide before reduction because oxides are easier to reduce.

a) Conversion to oxide

i) Calcination : It involves heating. It removes the volatile matter which escapes leaving behind the metal oxide.

$$Fe_2O_3 \cdot xH_2O \xrightarrow{\Delta} Fe_2O_3 + xH_2O$$

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

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

$$CaCO_3 \cdot MgCO_3 \xrightarrow{\Delta} CaO + MgO + 2CO_2$$

ii) Roasting : It is a process in which ore is heated in a regular supply of air in a furnance at a temp. below the M.P.

$$\therefore ZnS + O_2 \longrightarrow ZnO + SO_2$$

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

$$PbS + O_2 \longrightarrow PbO + SO_2$$

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$$

$$Cu_2S + O_2 \longrightarrow Cu_2O + SO_2$$

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

b) Reduction of Oxide to the metal

- Reduction of the metal oxide usual involves heating it with a reducing agent. for eg:- C or CO.
- The reducing agent (eg. Carbon) combines with Oxygen of the metal Oxide.

$CuO + C \longrightarrow Cu + CO$

$M_xO_y + yC \longrightarrow xM + yCO$

3) Extraction of Metals from their Oxides

Thermodynamic Principles of Metallurgy

$\Delta G_r = \Delta H - T\Delta S$

$\Delta G_r = 0$ equilibrium

When temperature is inc., ΔS becomes more +ve & hence ΔG_r becomes more -ve making the process more feasible.

$MO_2 \longrightarrow M + O_2$

$\Delta G_r = -RT \ln K_c$ $\Delta G_r < 0$ -ve spontaneous

On increasing the temp. & increasing value of K_c (ore^n moving in forward direction) ΔG_r becomes more -ve & re^n becomes more spontaneous $\Delta G_r > 0$ +ve Non-spontaneous

→ Ellingham Diagram $M + O_2 \longrightarrow MO$

→ These are the plots b/w ΔG_r of formation of oxides of elements and temperature.

→ The element whose graphs lies below that of the other will reduce the other elements.

→ The ΔG_f of R.A should always be more -ve than that of the metal to be reduced.

→ ΔG_f for the formation of oxide is always -ve and hence the ΔG_f for reverse reaction is always +ve.

$$M + O_2 \longrightarrow MO_2 \qquad \Delta G_f = -ve$$

$$MO_2' \longrightarrow M + O_2 \qquad \Delta G_f = +ve$$

$$C + O_2 \longrightarrow CO_2 \qquad \Delta G_f = -ve$$

C will be able to reduce this metal only if ΔG_f continue for the reaction is -ve.

→ The reduction of upper line is feasible by lower line element. If the difference is large the differences is easier.

→ The line of ΔG with more -ve will reduce ΔG with +ve.

* Applications :

a) Extraction of iron from its o__des.

Zone of reduction:

$$Fe_2O_3 + CO \longrightarrow Fe_3O_4 + CO_2$$

$$Fe_3O_4 + CO \longrightarrow FeO + CO_2$$

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

Zone of slag formation:

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

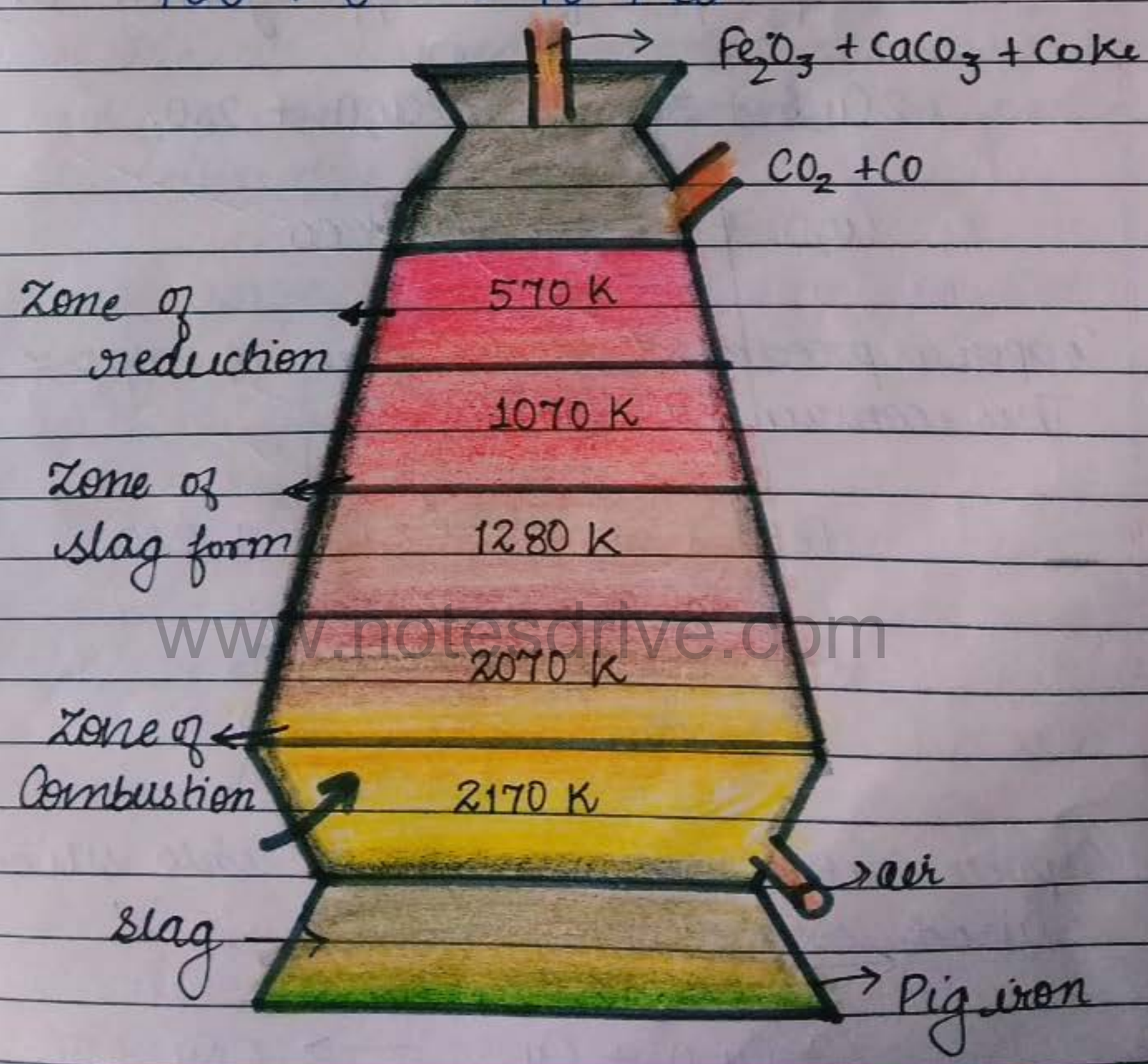
slag.

Zone of combustion:

$$C + O_2 \longrightarrow CO_2$$

$$CO_2 + C \longrightarrow 2CO$$

$$FeO + C \longrightarrow Fe + CO$$



* Pig iron is impure form of Iron.

→ Caste iron: It is prepared from Pig Iron by melting it with scrap iron and coke. It is hard and brittle.

→ Wrought Iron: It is prepared from caste iron and is purest form of iron. It is malleable.

b) Extraction of Copper from cuprous oxide [Copper (I) oxide]

Extraction of copper from Copper glance (Cu_2S)

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

$$Cu_2O + O \longrightarrow 2Cu + CO$$

Copper is produced in the form of copper matte. This contain Cu_2S and FeS.

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

$$FeO + \underbrace{SiO_2}_{\text{Flux}} \longrightarrow FeSiO_3 \quad (\text{slag})$$

Copper matte is then charged into silica lined converter.

$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$

NOTE :

Copper is extracted from low-grade ores by using Hydrometallurgy.

$$Cu^{2+} + H_2 \longrightarrow Cu + 2H^+$$

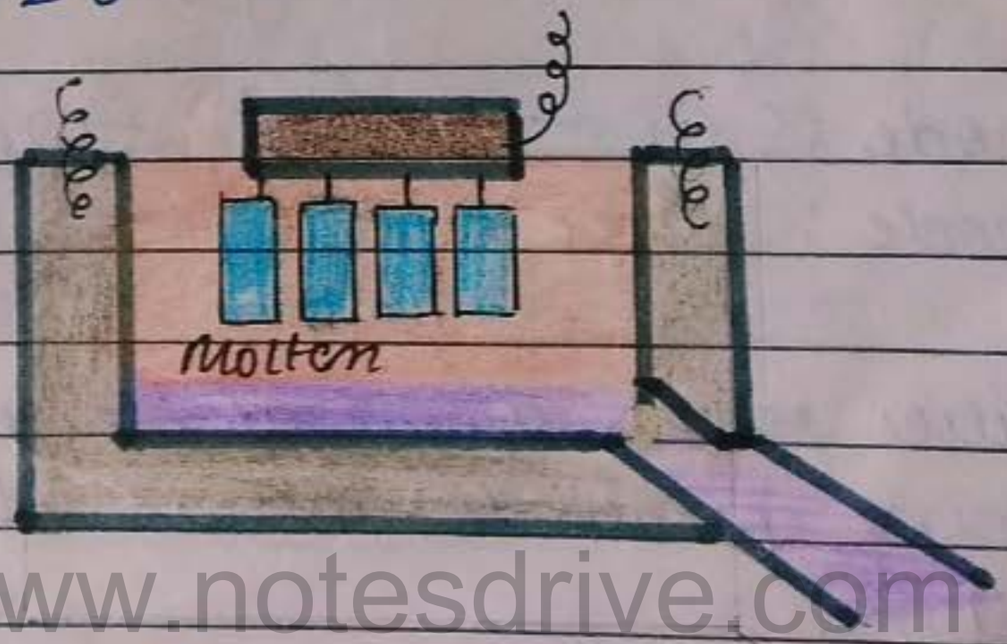
c) Extraction of Zinc from Zinc Oxide

$$ZnO + C \longrightarrow Zn + CO$$

★ Metallurgy of Aluminium

Alumina is mixed with cryolite (Na_3AlF_6) or CaF_2 to increase conductivity and lower melting point. The electrolysis is called Hall-Heroult Process.

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$



Cathode : $Al^{3+}(melt) + 3e^- \longrightarrow Al(l)$

Anode : $C(s) + O^{2-}(melt) \longrightarrow CO(g) + 2e^-$

$C(s) + 2O^{2-}(melt) \longrightarrow CO_2(g) + 4e^-$

4) Refining of Metals

The process of removal of Impurities from extracted metal is Refining.

a) **Distillation**

This is useful for low Boiling metals like Zn and Hg. Impure metal is evaporated to obtain pure metal as distillate.

b) **Liquation**

In this, low melting metals like Tin can be made to flow on sloping surface.

c) **Electrolytic refining.**

Used in refining of metals like Cu.

Anode : Impure metal
Cathode : Pure metal
Eg:-

$$\text{Anode : } Cu \longrightarrow Cu^{2+} + 2e^-$$
$$\text{Cathode : } Cu^{2+} + 2e^- \longrightarrow Cu$$

Impurities settle down as Anode mud containing precious metals like gold, platinum..

d) **Zinc Refining**

Principle: Impurities are more soluble in melt than in solid state of metal.
Eg. Si, Cu, B, etc.

e) Vapour Phase Refining

Principle : a) Metal should form a volatile compound with ava. reagent

b) Volatile compound formed should be easily decomposable.

* Mond Process

Used for refining of Nickel

$$Ni + 4CO \xrightarrow{340\ K} [Ni(CO)_4]$$

$$[Ni(CO_4)] \xrightarrow[460\ K]{\Delta} Ni + 4CO$$

* Arkel Method

Used for refining of Zirconium / Titanium.

$$Zr + 2I_2 \longrightarrow ZrI_4$$

$$ZrI_4 \longrightarrow Zr + 2I_2$$

f) Chromatographic Methods

Principle : Different components of a mixture are adsorbed to different extend on an adsorbent.