CHAPTER-7
METALLURGY

Revision Notes

The **elements** are the basic building blocks of matter. There are about 120 elements known till now. To study the characteristics and the properties of all these elements in simpler way, they are divided into two categories i.e., metals and non-metals.

- **Minerals:** Minerals are naturally occurring compounds of metals which are generally mixed with other substances such as silica, limestone, etc. These earthy impurities are called gangue or matrix.
- **Ores:** Ores are those minerals from which metals are extracted commercially at a comparatively lower cost and with minimum effort.
- **Occurrence of metals:** Most of the metals are reactive so they occur in combined state in the form of their oxides, carbonates, halides, sulphides, sulphates, etc., mixed with mud, clay, sand and stone.

Metals	Main ores
K	Carnallite ($KCl.MgCl_2.6H_2O$)
Na	Rock salt (NaCl) (in sea water)
Ca	Limestone, Marble ($CaCO_3$), Calcium sulphate dihydrate or Gypsum ($CaSO_4.2H_2O$),
Mg	Carnallite ($KCl.MgCl_2.6H_2O$), Magnesite ($MgCO_3$)
Pb	Galena (PbS)
Cu	Copper pyrites ($CuFeS_2$)
Hg	Cinnabar (HgS)
Ag	Argentite (Ag_2S) Horn silver (AgCl)

- **Extraction of Metals:**

  Extraction of a metal from its ore consists of the following processes:

  1. **Crushing and grinding:** Ores are crushed into a fine powder in big jaw crushers and ball mills. This process is called **pulverisation**.
  2. **Concentration (Dressing) of ores:** The process of removing gangue, the rocky impurities like SiO_2 present in an ore is called **concentration of an ore** or **ore dressing** and the purified ore is called **concentrated ore.**

➢ **Chemical Separation Bayer's Process**

This method makes use of difference between the chemical properties of the ore and the gangue. Bauxite ore is impure aluminium oxide ($Al_2O_3.2H_2O$) containing iron (III) oxide (Fe_2O_3) and silica (SiO_2) as the main impurities. Bayer's process is used to obtain pure aluminium oxide from bauxite ore. In this method of chemical purification, the finely powdered ore is treated with hot sodium hydroxide solution.

$$\underset{\text{[Impure bauxite]}}{Al_2O_3.2H_2O} + \underset{\text{[Conc.solution]}}{2NaOH} \xrightarrow{150-200^\circ C} \underset{\text{[Sodium aluminate]}}{2NaAlO_2} + 3H_2O$$

$$\underset{\text{[sodium aluminate]}}{NaAlO_2} + 2H_2O \xrightarrow{50-60^\circ C} \underset{\text{[Sodium hydroxide]}}{NaOH} + \underset{\text{[Aluminium hydroxide]}}{Al(OH)_3}\downarrow$$

$$\underset{\text{[Aluminium hydroxide]}}{2Al(OH)_3} \xrightarrow{1100^\circ C} \underset{\text{[Pure alumina]}}{Al_2O_3} + 3H_2O$$

Reduction by aluminium: The oxides of metals of chromium or manganese cannot be reduced by conventional reducing agents. These metal oxides can be reduced by aluminium powder. This method of reduction is also known as **Thermite process.**

$$3MnO_2 + 4Al \xrightarrow{Heat} 2Al_2O_3 + 3Mn + \text{Heat energy}$$

$$Cr_2O_3 + 2Al \xrightarrow{Heat} Al_2O_3 + 2Cr + \text{Heat energy}$$

➢ **Common Ores of Iron, Aluminium and Zinc**

Ores of Al	Chemical Name	Formula
(a) Ores of Al		
Bauxite	Hydrated aluminium oxide	$Al_2O_3 . 2H_2O$
Cryolite	Sodium aluminium fluoride	Na_3AlF_6
Corundum	Anhydrous aluminium oxide	Al_2O_3
(b) Ores of Fe		
Red haematite	Anhydrous ferric oxide	Fe_2O_3
Brown haematite	Hydrated ferric oxide	$2Fe_2O_3 . 3H_2O$
Magnetite	Triferric tetraoxide	Fe_3O_4
Iron pyrite	Iron disulphide	FeS_2
Siderite	Ferrous carbonate	$FeCO_3$
(c) Ores of Zn		
Zinc blende	Zinc sulphide	ZnS
Zincite	Zinc oxide	ZnO
Calamine	Zinc carbonate	$ZnCO_3$

➢ **Metallurgy of Aluminium**

(i) Occurrence: It is a highly electropositive metal and it does not occur in free state.

(ii) Purification of Ore: Most of aluminium is extracted from bauxite which contains ferric oxide (Fe_2O_3) and silica (SiO_2) as impurities crushed ore is subjected to electromagnetic separation to remove ferric oxide and then concentrated by Bayer's process or Hall's process.

(iii) Hall-Heroult's Process: (Bayer's Process)

(iv) Electrolytic Vessel: Iron tank lined with heat resistant material like carbon with a sloping floor for removal of molten aluminium.

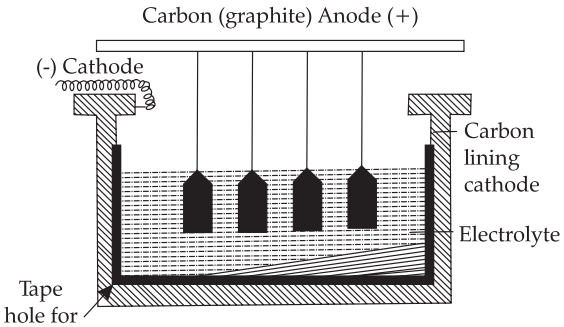
(v) Electrolyte: It is a molten mixture of alumina, cryolite, fluorspar.

(vi) Electrodes — Anode: Thick carbon rods

Cathode: Tank with carbon lining.

(vii) Temperature: 950°C

A layer of powdered coke is sprinkled over the surface of the electrolytic mixture. This reduces the heat loss by radiation and prevents carbon anode from burning in air.



Extraction of Aluminium

(viii) Reactions:

Alumina

$Al_2O_3 \rightleftharpoons 2Al^{3+} + 3O^{2-}$

At cathode: Carbon lining (gas carbon) of the cell.

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

At anode: Thick rods of graphite are suspended into the fused electrolyte.

$$6O^{2-} - 12\ e^- \longrightarrow 6[O]$$

$$3O + 3O \longrightarrow 3O_2$$

Anode is oxidised to carbon monoxide and then to carbon dioxide.

$$2C + O_2 \longrightarrow 2CO$$

$$2CO + O_2 \longrightarrow 2CO_2$$

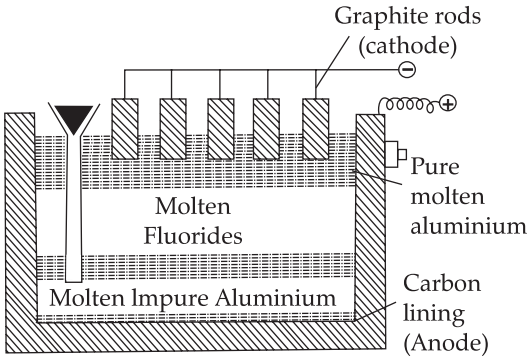
The oxygen evolved at the anode escapes as a gas or reacts with carbon anode. The carbon anode is thus oxidised. The carbon anode is, hence consumed and renewed periodically after a certain period of usage. Further purification can be done by electrolysis.

➢ **Refining of Aluminium (Hoope's Electrolytic process) :**

The process uses an electrolytic cell which contains three layer of molten substance of differing specific gravity. Molten impure aluminium forms the bottom layer. The bottom layer has carbon lining and serves as anode. Pure molten aluminium with carbon electrodes serves as cathode in the top layer. The middle layer consists of a mixture of fluorides of sodium barium and aluminium. Lower layer consists of impure Al at bottom along with carbon lining.

Anode: $\underset{\text{(Impure)}}{Al} - 3e^- \rightarrow Al^{3+}$

Cathode: $Al^{3+} + 3e^- \rightarrow \underset{\text{(Pure)}}{Al}$



Refining of Aluminium

➢ **Alloy:** Alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

➢ **Common Alloys, their Compositions, Properties and Uses:**

Principal metal	Alloy's name	Composition	Properties	Used for making
Aluminium	1. Duralumin	95% Al 4% Cu 0.5% Mg 0.5% Mn	1. Light but as strong as steel. 2. Hard and resistant to corrosion. 3. Highly ductile.	1. Bodies of aircraft, buses and tube trains. 2. Light tools 3. Pressure cooker.
	2. Magnalium	90-95% Al 10-5% Mg	1. Resists corrosion 2. Light 3. Strong	1. Aircraft 2. Scientific instruments 3. Metal mirrors 4. Light tools 5. Beams of balance 6. Household appliances

	3. Alnico	Al,Ni,Co,Fe	1. Light 2. Shiny 3. Resists corrosion	Magnets
Iron	1. Stainless steel	73% Fe, 18% Cr, 8% Ni, 1% C	1. Resists corrosion 2. Lustrous, hard 3. Resistant to acids and alkalis	1. Utensils 2. Cutlery 3. Ornamental pieces 4. Surgical instruments
	2. Manganese steel	85% Fe, 1% C, 14% Mn	1. Durable, tough and hard	1. Safes 2. Rock drills 3. Armour plates
	3. Tungsten	84% Fe, 5% W, 1%C,	1. Very hard	1. Cutting tools for high speed lathes
	4. Nickel steel	95-98%Fe 5-3% Ni	1. Hard and elastic 2. Resistant to corrosion	1. Electric wire cables 2. Automobile parts
	5. Invar	Fe 63%, Ni 36% C 1%	1. Negligible expansion	1. Metre scales 2. Scientific instruments
Zinc and copper	1. Brass	60-70% Cu 40-30% Zn	1. Malleable and ductile. 2. Can be easily cast. 3. Resists corrosion. 4. Yellow/silvery in colour.	1. Decorative hardware, utensils. 2. Screws and handles. 3. Cartridge containers. 4. Parts of watches . 5. Musical instruments. 6. Electrical goods.
	2. Bronze	80% Cu 18% Sn 2% Zn	1. Hard and easily cast. 2. Can take up polish. 3. Resists corrosion.	1. Medals 2. Statues 3. Utensils 4. Bearings and 5. Coins
	3. German silver	50% Cu 30% Sn 20% Zn	1. White and light like silver. 2. Malleable and ductile. 3. High electrical resistance.	1. Decorative articles. 2. Electric heaters, rheostats. 3. Resistors
	4. Bell metal	78% Cu 22% Sn	1. Sonorous (produces sound). 2. Hard and brittle.	1. Bell, gongs. 2. Statues.
	5. Gun metal	Cu 88%, Sn 8%, Zn 1%, Pb 1%	1. Hard and brittle 2. Easily cut	1. Barrels of cannons. 2. Bearings, gears, etc.
Lead	1. Solder or Fuse metal	Pb, Sn	1. Low melting point, high tensile strength	1. Welding 2. Fuse
	2. Type metal	75%Pb, 15% Sb, 10% Sn	1. Low melting point, easily cast.	1. For printing blocks.

Mnemonics

1. **Concept:** Ores of Iron
   Mnemonics:
   RB Hema **M**asi is my **s**ister
   Interpretation:
   R: Red Haematite
   B: Brown
   He: Haematite
   Ma: Magnetite
   Si: Siderite
2. **Concept:** Ores of zinc
   Mnemonics:
   z z z.....
   Interpretation:
   Zinc blende
   Zinc calamine
   Zincite

Key Words

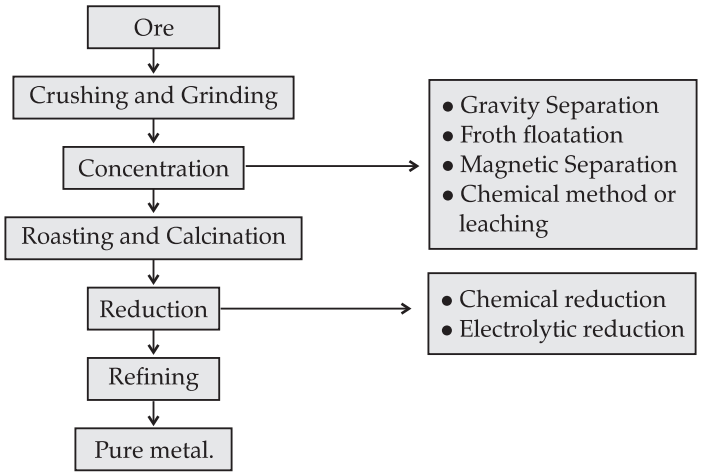
- **Metallurgy:** The process used for the extraction of metals in their pure form from their ores is referred to as metallurgy. It also deals with the production and purification of metals and manufacture of alloys.
- **Minerals:** The naturally occurring compounds of metals which are generally mixed with other matter such as soil, sand, limestone and rocks are known as minerals.
- **Ores:** These are the minerals from which the metals can be extracted conveniently and economically.
- **Flux:** It is a substance added to the charge in a furnace during smelting (or reduction) to remove gangue. The flux normally added in any metallurgical process is lime (CaO).
- **Slag:** It is a fusible product formed when flux combines with gangue during the extraction of metals.

  For example: $\text{Gangue} + \text{Flux} \longrightarrow \text{Slag}$

  $$SiO_2 + CaO \longrightarrow CaSiO_3$$
- **Fusible alloy:** An alloy melting in the range of about 57°C to 260°C, usually contains bismuth, lead, tin, etc. These alloys are called fusible alloys.
- **Amalgam:** A mixture or an alloy of mercury with a number of metals alloys such as sodium, zinc, gold and silver as well as with some non-metals is known as amalgam.

Key Terms

- **Flow Chart for extraction of metal from its ore:**

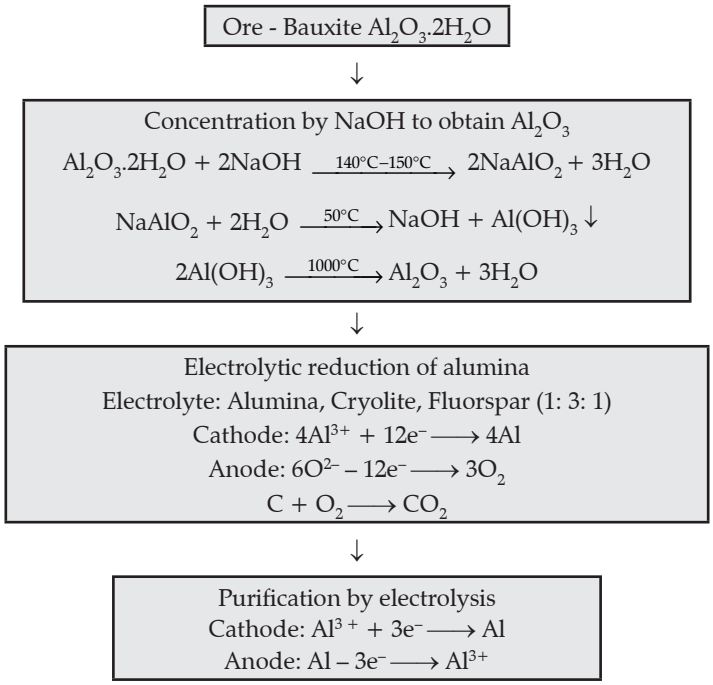


- Sulphide ores like Zinc blende (ZnS) and Galena (PbS) are lighter than the impurities present. They are concentrated by froth flotation process.
- The selection of reducing agents depends upon the position of the metal in the reactivity series.
- Oxides of highly active metals like potassium, sodium, calcium, magnesium and aluminium have great affinity towards oxygen and so cannot be reduced by common reducing agents like coke (carbon), carbon monoxide or hydrogen.
- Reactive metals can not be extracted from their aqueous salt solutions by electrolysis as they can react with water.
- The highly reactive metals can be used as reducing agents because they can displace metals of lower reactivity from their compounds . For example, in order to obtain manganese, its oxide is heated with aluminium powder.

  $$3\,MnO_2\,(s) + 4Al\,(s) \longrightarrow 3Mn\,(l) + 2Al_2O_3\,(s) + \text{Heat.}$$
- Aluminium is a powerful used as reducing agent . When the mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is called aluminothermy.

  $$Fe_2O_3 + 2Al \longrightarrow 2Fe + Al_2O_3 + \text{Heat.}$$
- Refining is the process by which crust metal is purified.
- Aluminium is the most abundant metal in the earth crust.
- Aluminium is extracted from its main ore bauxite $Al_2O_3.2H_2O$. Bauxite contains 60% Al_2O_3 the rest bring sand, ferric oxide and titanium oxide.
- Cryolite lowers the fusion temperature from 2050°C to 950°C and enhances conductivity.

- Fluorspar and cryolite act as a solvent for the electrolytic mixture and increases its conductivity since pure alumina is almost a non-conductor of electricity.
- Powdered coke is sprinkled over the surface of the electrolytic mixture. It reduces heat loss by radiation and prevent the burning of anode.
- An alloy melting in the range of about 51°C to 260°C, usually contains bismuth, lead, tin, etc. These alloys are called fusible alloys.
- The purpose of an alloy is to improve specific usefulness of the primary component and not to adulterate or degrade it.
- **Flow Chart for extraction of aluminium:**



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