METALLURGY AND ALLOY

Introduction:

- **Flux:** 'A substance which is used to remove the gangue from ore is called as flux'. Ex. CaO, SiO_2

- **Metallurgy:** It is a process of extraction of metals from their ores economically & profitably.

- **Gangue/Matrix:** 'A impurities associated with ore is called as gangue'.

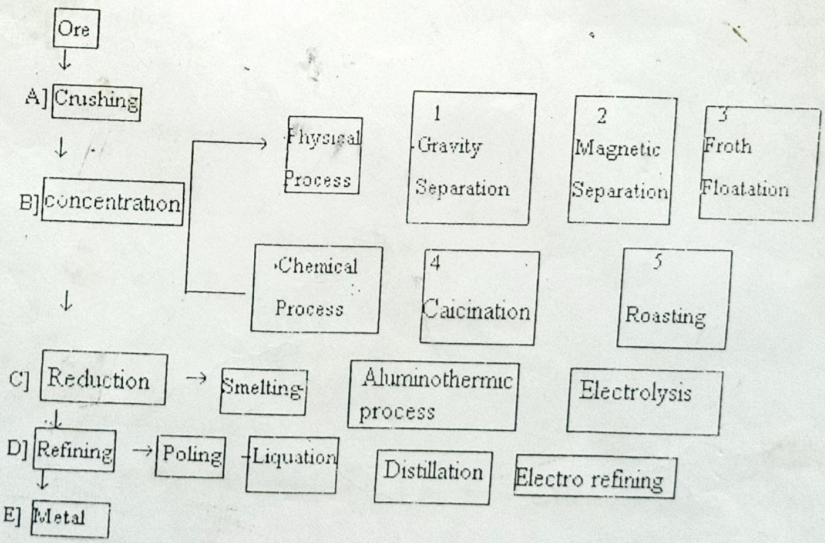
- **Mineral:** A naturally occurring substance present in earth's crust which contains metal the free or combined state is known as mineral.
  Ex. chalcopyrite [Cu_2S, Fe_2S_3], Sphalerite [ZnS], calcite [$CaCO_3$], Fluorspar [CaF_2], Quartz [SiO_2].

- **Ore:** A minerals from which the metal can be extracted economically is known as ore.

- Clay and bauxite are two minerals of aluminium but aluminium can be profitably extracted only from bauxite not from clay, hence bauxite is an ore while clay is mineral of aluminium.

Flow chart for extraction of metal:

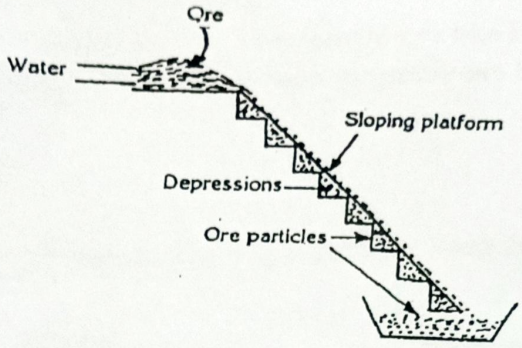
- Flow chart for extraction of Metal from the ore.



Concentration of Ore:

- The process of removal unwanted materials like sand, clay, rocks etc from the ore is known as concentration

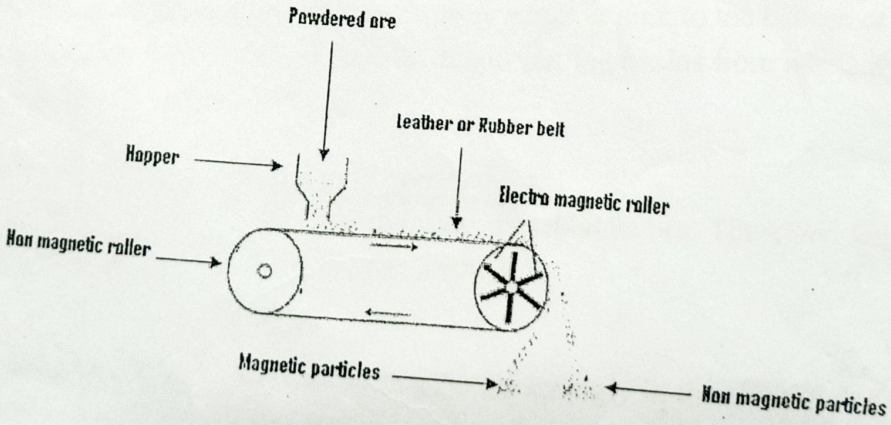
Gravity separation method:



Gravity separation:

- It is a process of concentration of ore to remove gangue from crushed ore under gravity.
- In this process ore is mixed with water and washed by directing it on inclined surface having depressions.
- The lighter sandy and clay impurities are washed away. While heavier ore particles are left behind in the depressions as shown in the Fig.
- Gravity separation is suitable for oxide ores like Haematite ores.

Electromagnetic separation method:



- This method is based upon magnetism

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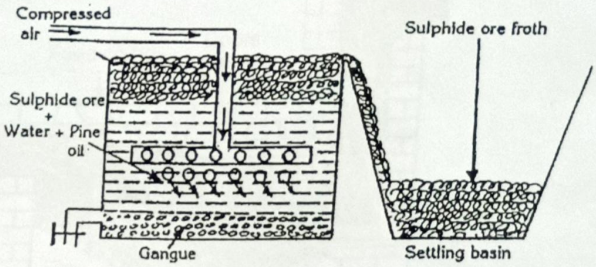
- In this process powdered ore is allowed to fall through hopper on leather or rubber b which is constantly moving over two rollers one of which is electromagnetic in natu
- The magnetic particles present in the ore when come in contact with the magnetic fi the electromagnetic roller they get attracted towards the roller and hence get collecte near the roller, while non magnetic particles present in the ore are not attracted towa the roller hence fall away from the roller.
- This process is used for concentration of magnetic ore like Haematite which contains magnetic impurities and concentration of non magnetic ore like Tinstone which conta magnetic impurities

Froth Floatation Process.

- The process used for concentration of Sulphide ore is Froth Floatation Process.



- In this process, the powdered sulphide ore is mixed with water & pine oil.
- The whole mixture is then stirred vigorously by passing compressed air.
- The oil forms froth with air bubbles.
- The sulphide ore particles get attached with the Froth & Floats on the surface, while the gangue or earthy impurities are wetted by water & sink to the bottom of the tank.
- The floating froth is then skimmed off into settling basins from where by filter press a concentrated ore is recovered.

Conversion of ore into oxide (Ore to metaloxide):

- It is easier to reduce oxide than sulphide or carbonate ore. Therefore, the given ore should be converted into oxide by suitable method

Calcination:

- 'Calcination is the process of heating the ore strongly in the absence of air to a temperature insufficient to melt it.'
- It is done in the hearth of a reverberatory furnace when the doors are kept closed. (i.e. in absence of air).
- Generally, carbonate & hydroxide ores are concentrated by this method.

❖ Purposes of Calcination:

❖ To convert carbonate & hydroxide ore into oxide.

$$CaCO_3 \longrightarrow CaO + CO_2\uparrow$$

(Limestone)

$$CuCO_3.Cu(OH)_2 \longrightarrow 2CuO + CO_2\uparrow + H2O\uparrow$$

(Malachite)

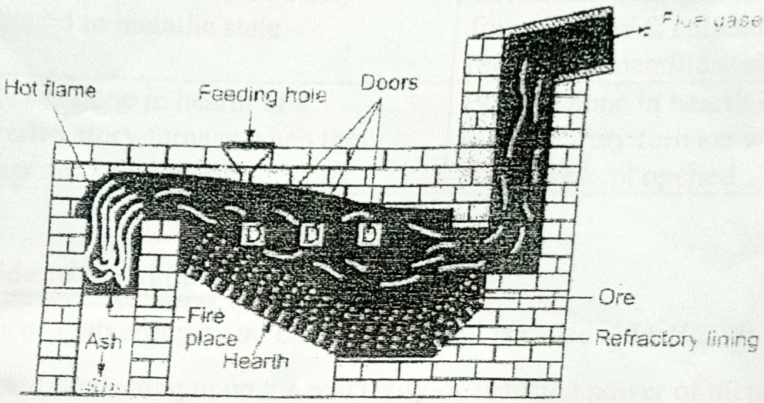
❖ To remove the moisture.

$$Fe_2O_3.3H_2O \longrightarrow Fe_2O_3 + 3H_2O$$

(Haematite)

❖ To remove the volatile impurities.

❖ To make mass porous, so that it can be easily reduced to the metallic state.



Roasting

❖ 'Roasting is the process of heating the ore strongly in excess of air below its M.P.'

❖ This process is used to convert sulphide into oxide & sulphate

❖ Some of the reactions involving sulphide ores are

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

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

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

❖ It removes moisture & oxidation of ore & the impurities like S, P, As etc.

❖ In roasting, the sulphide ore chemically changed into suitable form (oxides & sulphates) can be reduced to metallic state.

❖ This Process is done in hearth of a reverberatory furnace when the doors are kept opened

Differentiate between calcination and roasting.

	Calcination	Roasting
1)	Process of heating the ore strongly in absence of air below its M.P.	Process of heating the ore strongly in excess of air below its M.P.
2)	This process is used to convert carbonate & hydroxide into their oxides	This process is used to convert sulphide into oxide & sulphate
3)	Purpose is to remove the moisture & volatile impurities from the ore	Purpose is to remove moisture & oxidation of ore & the impurities like S,P,As etc.
4)	In calcination, the mass becomes porous, so that it can be easily reduced to metallic state	In roasting, the sulphide ore chemically changed into suitable form (oxides & sulphates) can be reduced to metallic state.
5)	Process done in hearth of a reverberatory furnace when the doors are kept closed.	Process done in hearth of a reverberatory furnace when the doors are kept opened

Reduction of oxide to metal (metaloxide to metal):

- The process of converting metal oxide into metal is called reduction. It needs a suitable reducing agent depending upon the reactivity or reducing power of metal.
- The common reducing agents used are carbon or carbon monoxide or any other metals like Al, Mg etc.
- One or more of the following methods can be used to obtain a metal from its oxide.

Heating:

- Less reactive metals like silver and mercury can be obtained by heating their oxides alone.
- These metals are placed at the bottom of the electrochemical series.

$$2\,HgO \rightarrow 2\,Hg + O_2$$

$$2\,Ag_2O \rightarrow 4Ag + O_2$$

Carbon reduction:

- Some metals like lead, copper, zinc and iron can be obtained by reducing their oxides by carbon.

- When the oxides of these metals are heated with coke, the oxides are reduced to a me
- Carbon has more affinity for oxygen than the metals have it for oxygen hence carbon extracts the oxygen leaving behind the free metal.

$$PbO + C \rightarrow Pb + CO$$

$$CuO + C \rightarrow Cu + CO$$

$$ZnO + C \rightarrow Zn + CO$$

$$Fe_2O_3 + 3\,C \rightarrow 2\,Fe + 3CO$$

Use of carbon monoxide:

- Oxides of metals like PbO, CuO, FeO can be reduced by carbon monoxide at high temperature to give the corresponding metals.

$$CuO + CO \rightarrow Cu + CO2$$

$$FeO + CO \rightarrow Fe + CO2$$

$$PbO + CO \rightarrow Pb + CO2$$

Use of aluminium(Alumino-thermo process):

- Oxides of metals like ZnO, Cr_2O_3 and MnO_2 can not be reduced by carbon because these metals have a greater affinity for oxygen than carbon.
- An active metal like aluminium (in the form of powder) is required to reduce the oxides of these metals.
- The reduction of a metal oxide by heating with aluminium is called aluminothermy.
- In this process, lot of heat is evolved and hence the metal may melt in the container.
- It is tapped from the bottom of the container.

$$Cr_2O_3 + 2\,Al \rightarrow Al_2O_3 + 2\,Cr + Heat$$

$$3\,MnO_2 + 4Al \rightarrow 2\,Al_2O_3 + 3\,Mn + Heat$$

Electrolysis:

- The metals like iron, zinc, lead, chromium, manganese lie in the middle of the electrochemical series. They are somewhat active. So their oxides can be reduced by carbon or carbon monoxide or reactive metals like aluminium or sodium, calcium.

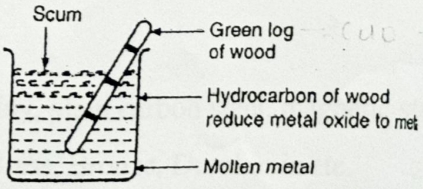
- But the metals like sodium, magnesium, calcium, aluminium which are placed in the t of the electrochemical series i.e. which are very active, can not be obtained by the reduction of their oxides by ordinary reducing agents.
- So they are obtained by passing an electric current through the purified molten ore.
- An electric current is passed through the molten oxide or chloride of the metal. The me gets deposited at the cathode from where it is separated

Purification of metal (Refining):

- It is the process of converting an impure metal into pure metal depending upon the natu of metal.

Poling (oxidation) method:

- When the impurity has greater affinity for oxygen than the metal itself, then this method is used.
- This method consists of stirring the hot crude molten metal with green logs of wood.
- The wood gases (Hydrocarbons like methane etc.) so produced reduce any metal oxide impurity present in the metallic form.
- Moreover, during stirring large quantity of air is absorbed by the molten metal and such absorbed air oxidizes the easily oxidisable impurities.
- The oxidized impurities escape either as vapour or form 'scum' over molten metal. The scum so formed is removed by perforated ladle.



Liquation: technique for separating constituent of an ore, a metal, or an alloy. by partial melt

- Those metals which have impurities whose melting points are higher than metal can be purified by this method.

- In this method, Sn metal can be purified. Tin containing iron as impurities heated on top of sloping furnace. Tin melts and flows down the sloping surface where iron is left behind and pure tin is obtained.

Distillation:

- It is the process used to purify those metals which have low boiling points, e.g., zinc, mercury, sodium, potassium.
- Impure metal is heated so as to convert it into vapours which changes into pure metal c condensation and is obtained as distillate.

Electrolytic refining:

- In this method, impure metal is taken as anode, pure metal is taken as cathode, and soluble salt of metal is used as electrolyte.
- When electric current is passed, impure metal forms metal ions which are discharged a cathode forming pure metal
- At anode: $M \rightarrow M^{n+} + ne^-$

  (Impure)
- At cathode: $Mn^+ + ne^- \rightarrow M$

  (Pure)

Define Alloy. Give the classification of Alloy with one example of each.

- **Alloy:** It is defined as a homogeneous mixture of two or more elements in which one must be a metal.

Classification of Alloys:

- Ferrous Alloys: Ex. steel alloy, plain carbon steel, magnetic steel, stainless steel etc.
- Non - Ferrous Alloys: Ex. Brass, Bronze, Duralumin etc.

Purpose of making Alloys:

- Pure metals are alloyed with other elements because
- All metals are not abundant.
- All metals bear different properties.
- Use of any single metal is not economical.

- Besides this, alloying will modify some important properties of parent (i.e. base metal) as described below.

To modify mechanical properties:

Most of the mechanical properties can be improved by alloying base metal with proper elements.

a) Strength: The strength of Al can be increased by alloying it with Cu which gives Duralumin.
b) Toughness: The toughness of Cu can be increased by alloying it with Zn which gives Cartridge brass [Cu + Zn].
c) Ductility and malleability: Ductility and malleability can be controlled by alloying as per requirements
d) Hardness: Hardness of Fe can be increased by alloying it with C which gives Steel [Fe + C]

To modify forming Properties:

- Alloying improves the forming properties, so that metallic material can be easily shaped. E.g. cartridge brass can be easily cold worked, while leaded brass can be easily machined.

To improve the corrosion resistance:

- To improve resistance to weathering, alloying is essential. E.g. Stainless steel i.e. an alloy of Fe with Carbon, Chromium and Nickel is 100% corrosion resistance.

To modify colour:

- Excellent colour appearance is possible with metallic materials due to alloying.
- E.g. When Zn/Sn is added to Cu the colour changes from red to yellow while when 10% of Al is added to Cu the colour changes from red to golden.

To reduce the melting point:

- Pure metals have high melting point. Certain applications require metallic material with low melting point.
- When a metal is alloyed with some other element (as an impurity), its melting point is lowered.
- This property is made use of in preparing low melting alloys. E.g. Solders (m.p. 150-250°C) are alloys of lead and tin.

II) Bronze	Cu 75-95 Sn – 5-25	1. Hard than brass 2. resist to water and corrosion 3. Castable 4. Ductile and malleable	1.Pump lining 2.Bearing 3.Bushes, rods, wires 4. Household articles 5. Hydraulic pumps 6. stamping and drawing units

Alloys of Aluminum:-

I) Duralumin

II) Alnico

Name of Alloys	Composition (%)	Properties	Applications
I) Duralumin	Cu - 3.5 – 4.5 Mg - 0.3 – 1.0 Mn - 04 – 1.0 Si – 0.3 – 1.0 Al - 95.6 – 92.5	1.light, ductile, malleable 2. May be hardened 3. May be hardened by quenching at high temperature. 3. brittle up to certain extent	1. bars, sheets, tubes, window, partition frames and stamping material 2.aircraft construction 3.ship building 4. used for construction of light but high strength material.
II) Alnico :- Magnetic material with the incorporation of aluminum	***Alnico - I*** Al – 12, Ni – 20, Co – 6, Fe – 62 ***Alnico - II*** Al – 10, Ni – 18, Co – 12,Cu – 6, Fe – 54 ***Alnico - III*** Al – 12, Ni – 25, Fe – 63 ***Alnico - IV*** Al – 12, Ni – 28, Co – 5, Fe – 55 ***Alnico - V*** Al – 8, Ni – 14, Co – 24,Cu – 3, Fe – 51	1.Magnetic material is due to iron 2. moderate magnetic stability 3. resistance to external magnetic field,	1. Commercial magnetic materials particularly permanent magnetic material. 2

❖ Alloys of Nickel : Nichrome

Name of Alloys	Composition (%)	Properties	Applications
Nichrome	Ni -60, Cr – 12, Mn – 2 , Fe – 26 ***Chromel A*** Ni – 80, Cr – 20 ***Chromel C*** Ni – 60, Cr – 16 Fe -24	1.High electric resistivity, high M. P. 2. Rigid thermal stability 3. Good chemical resistivity 4. Resist to corrosion	1. Making heating elements in stoves, electric iron, toaster, microwave appliance those are stable up to 850^0C .

❖ Alloys of Tin

Name of Alloys	Composition (%)	Properties	Applications
Solder	Sn-50-67% Pb-50-33%	1. Soft 2. low M.P 3. Electrical Conductor	used in electronic industry for soldering electronic component

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