## Introduction

o Metals have lot of importance in our day to day life.
o Uses of metals:-
   o The buildings around us are made up of steel, iron; wires that carry current are made up of metals.
   o The bridges, tall towers are all made up of metals.
   o The vessels which are made up of stainless steel; the body of ships made up of metals.
   o The batteries, vehicles, engines are made up of metals.

Pure metals can be extracted from ores by some chemical reactions.

Understanding the Terms Minerals & Ores

o Mineral word is derived from the word 'Mine'.
o The naturally occurring substances in the form of which the metals occur in the earth crust are called **minerals**.
o Every mineral is not suitable for the extraction of the metal.
o The mineral from which the metal is economically and conveniently extracted is called an **ore**.
o Thus, all ores are minerals but all minerals are not ores.
o Impurities associated with ores are called **gangue** or matrix.
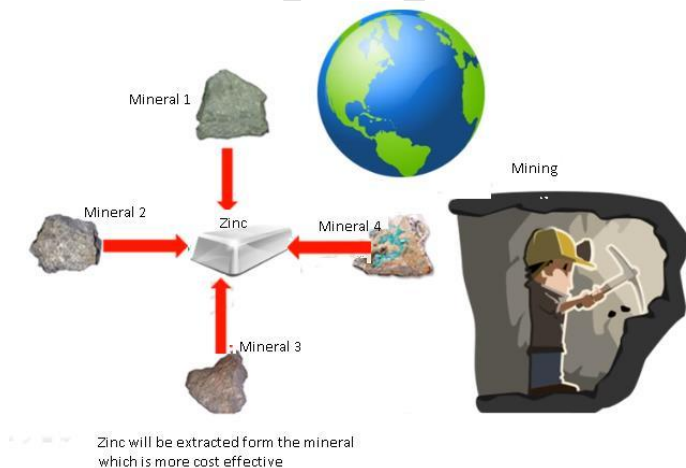
- o The extraction and isolation of metals from ores involve the following major steps:
  - o Concentration of the ore,
  - o Isolation of the metal from its concentrated ore, and
  - o Purification of the metal.
- o The entire scientific and technological process used for isolation of the metal from its ores is known as **Metallurgy**.
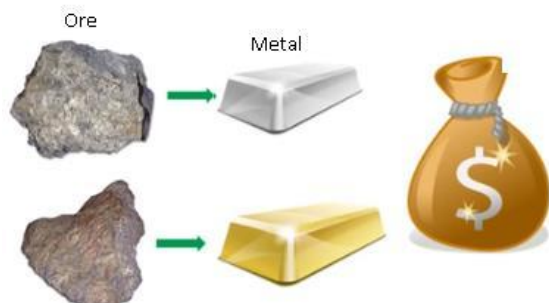
Occurrence of Metals

- o Earth crust is the source of many elements. Out of these elements, 70% are metals. Aluminium is the most abundant metal of earth crust and iron comes second.
- o The percentage of different elements in earth crust is:-
- o O-49%, Si-26%, Al-7.5%, Fe-4.2%, Ca-3.2%, Na-2.4%, K-2.3%, Mg-2.3%, H-l%
  - o Metals occur in two forms in nature:-
- o In native state
- o In combined state, depending upon their chemical reactivities.

Native State

Elements which have low chemical reactivity or noble metals having least electropositive character are not attacked by oxygen, moisture and CO_2 of the air. These elements, therefore, occur in the Free State or in the native state, e.g., Au, Ag, Pt, S, O, N, noble gases, etc.

Combined State

Highly reactive elements such as F, CI, Na, K, etc., occur in nature combined form as their compounds such as oxides, carbonates sulphides, halides, etc.

Hydrogen is the only non-metal which exists in oxidised form only.

Metal	Ores	Composition
Aluminium	Bauxite	$AlO_x(OH)_{3-2x}$ [where $0 < x < 1$]
	Kaolinite (a form of clay)	$[Al_2(OH)_4 Si_2O_5]$
Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
	Siderite	$FeCO_3$
	Iron pyrites	FeS_2
Copper	Copper pyrites	$CuFeS_2$
	Malachite	$CuCO_3.Cu(OH)_2$
	Cuprite	Cu_2O
	Copper glance	Cu_2S
Zinc	Zinc blende or Sphalerite	ZnS
	Calamine	$ZnCO_3$
	Zincite	ZnO

Extraction & Isolation of Metals

Following are the steps involved in extracting the metal, then isolating the impure metal from the ore and finally purify the metal.
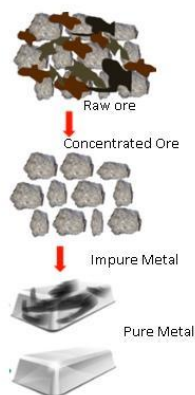
o **Concentration of the Ore**: - The first step is to remove the impurities from the ore and it does not involve any chemical process. It is based on the difference between the physical properties of the metal and the unwanted particles.
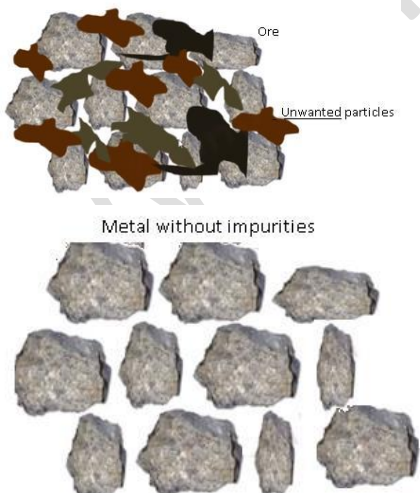
Following are the physical processes involved:-
1. Hydraulic Washing
2. Magnetic separation
3. Froth Flotation Method
4. Leaching

o **Isolation of the metal from its concentrated ore**: - This process involves of getting impure metal from its concentrated ore. It is a chemical process.
Following are the processes involved:-
1. Conversion of oxide (Calcination & Roasting) & Reduction to form metal.
2. Electrochemical Process
3. Oxidation reduction

o **Purification of the metal**: - It involves the purification of the metal.
Following are the processes involved:-
1. Distillation
2. Liquation
3. Electrolysis
4. Zone refining
5. Vapour phase refining
6. Chromatographic methods

Concentration of ores: -
1. Benefaction: - Removal of the unwanted materials (e.g., sand, clays, etc.) from the ore is known as **concentration**, **dressing** or **benefaction**. It involves several steps and selection of these steps depends upon the differences in physical properties of the compound of the metal present and that of the gangue.
2. Hydraulic Washing: - This method is based on the differences in gravities of the ore and the gangue particles. The process by which lighter earthy impurities are removed from the heavier ore particles by washing with water is called levigation. The lighter impurities are washed away. This method is commonly used for oxide ores such as haematite, tin stone and native ores of Au, Ag, etc.
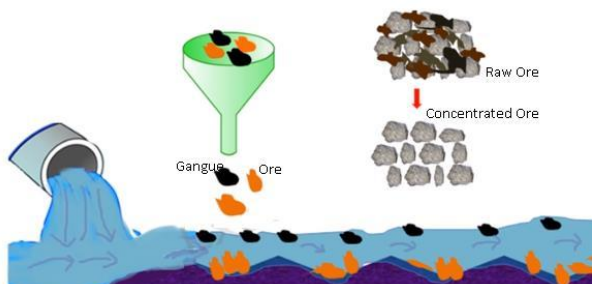
1. Magnetic Separation: - This method is based on differences in magnetic properties of the ore components. If either the ore or the gangue (one of these two) is capable of being attracted by a magnetic field, then such separations are carried out (e.g., in case of iron ores). The ground ore is carried on a conveyer belt which passes over a magnetic roller.

1. <u>Froth Flotation Method</u>: - In this method is use to remove gangue from sulphide ores. In this process, a suspension of the powdered ore is made with water. This method is based on the preferential wetting of ore particles by oil and that of gangue by water .As a result the ore particles become light and rise to the top in the form of froth while the gangue particles become heavy and settle down. Thus adsorption is involved in this method.

Working of Froth Flotation Method

1. It contains Collectors (e. g., pine oils, fatty acids, xanthates, etc.) which will enhance the non-wettability of the mineral particles and froth stabilisers (e. g., cresols, aniline) as a result it stabilises the froth.
2. The mineral particles become wet by oils while the gangue particles by water. A rotating paddle agitates the mixture and draws air in it. As a result, froth is formed which carries the mineral particles. The froth is light and is skimmed off. It is then dried for recovery of the ore particles.
3. Sometimes, it is possible to separate two sulphide ores by adjusting proportion of oil to water or by using '**depressants**'. For example, in case of an ore containing ZnS and PbS, the depressant used is NaCN. It selectively prevents ZnS from coming to the froth but allows PbS to come with the froth.
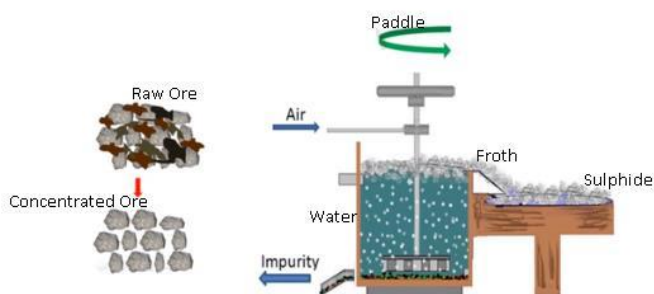

1. <u>Leaching</u>: - Leaching is often used if the ore is soluble in some suitable solvent.

Following are the examples to explain the process of leaching.

(a) <u>Leaching of alumina from bauxite</u> :-

The principal ore of aluminium, bauxite, usually contains SiO_2, iron oxides and titanium oxide (TiO_2) as impurities.

Concentration is carried out by digesting the powdered ore with a concentrated solution of NaOH at (473 – 523) K and (35 – 36) bar pressure.

This way, Al_2O_3 is leached out as sodium aluminate (and SiO_2 too as sodium silicate) leaving the impurities behind:

$Al_2O_{3(s)}$ + 2NaOH $_{(aq)}$ + 3H$_2$O $_{(l)}$ → 2Na [Al (OH) $_4$]$_{(aq)}$
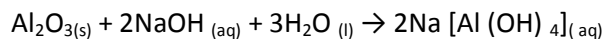
The aluminate in solution is neutralised by passing CO_2 gas and hydrated Al_2O_3 is precipitated. At this stage, the solution is seeded with freshly prepared samples of hydrated Al_2O_3 which induces the precipitation
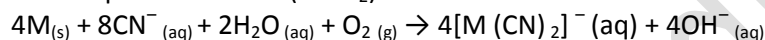
2Na [Al (OH) $_4$] $_{(aq)}$ + $CO_{2\,(g)}$ → Al_2O_3.xH$_2$O$_{(s)}$ + 2NaHCO$_{3\,(aq)}$
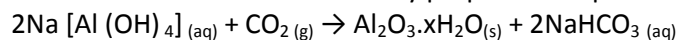
The sodium silicate remains in the solution and hydrated alumina is filtered, dried and heated to give back pure Al_2O_3:

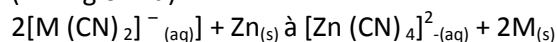Al_2O_3.xH$_2$O(s) à $Al_2O_{3(s)}$ + xH$_2$O $_{(g)}$ (Temp at 1470K)
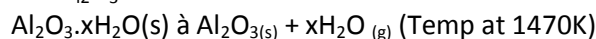
(b) Other examples

In the metallurgy of silver and that of gold, the respective metal is leached with a dilute solution of NaCN or KCN in the presence of air (for O_2) from which the metal is obtained later by replacement:

$4M_{(s)}$ + 8CN$^-$ $_{(aq)}$ + 2H$_2$O $_{(aq)}$ + O$_{2\,(g)}$ → 4[M (CN) $_2$] $^-$ (aq) + 4OH$^-$ $_{(aq)}$

(M= Ag or Au)

2[M (CN) $_2$] $^-$ $_{(aq)}$] + Zn$_{(s)}$ à [Zn (CN) $_4$]^2-$_{(aq)}$ + 2M$_{(s)}$

Extraction of Crude Metals from Concentrated Ore

The concentrated ore is usually converted to oxide before reduction, as oxides are easier to reduce.

Thus, isolation of crude metal from concentrated ore involves two major steps:

1. Conversion to oxide.
2. Reduction of the oxides to metal.

Conversion to oxide

o   Calcination: - It is the process of converting an ore into its oxides by heating it strongly, below its melting point in a limited supply of air or in absence of air.

During calcination, volatile impurities as well as organic matter and moisture are removed.

o   Fe$_2$ O$_3$ x H$_2$O (Δ)à Fe$_2$ O$_{3\,(s)}$ + x H$_2$ O $_{(g)}$
o   ZnCO$_{3\,(s)}$ (Δ)à ZnO(s) + CO$_{2\,(g)}$
o   Roasting: - In roasting, the ore is heated in a regular supply of air in a furnace at a temperature below the melting point of the metal. This process is commonly used for sulphide ores and is carried out in blast furnace or reverberatory furnace. Roasting helps to remove the non-metallic impurities and moisture.

Some of the reactions involving sulphide ores are:

o   2ZnS + 3O$_2$ → 2ZnO + 2SO$_2$
o   2PbS + 3O$_2$ → 2PbO + 2SO$_2$
o   2Cu$_2$S + 3O$_2$ → 2Cu$_2$O + 2SO$_2$

If the ore contains iron, it is mixed with silica before heating.

Iron oxide 'slags of' as iron silicate and copper is produced in the form of copper matte which contains Cu_2S and FeS.

o $FeO + SiO_2 \rightarrow FeSiO_3$
   o   (Slag)
o   <u>Meaning of slag</u>: - During metallurgy, 'flux' is added which combines with 'gangue' to form 'slag'. Slag separates more easily from the ore than the gangue. This way, removal of gangue becomes easier.
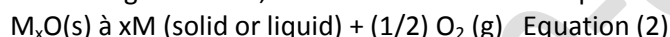
Reduction of oxide to the metal

o   The roasted or the calcined ore is then converted to the free metal by reduction. Reduction method depends upon the activity of metal.
o   Metals which are low in the activity series (like Cu, Hg, and Au) are obtained by heating their compounds in air: metals which are in the middle of the activity "cries (like Fe. Zn, Ni, Sn) are obtained by heating their oxides with carbon while metals which are very high in the activity series (e.g., Na, K, Ca, Mg, Al) are obtained by electrolytic reduction method.
o   Using the concepts of thermodynamics will help us to know the metallurgical transformations.
   o   Gibb's Energy:- The change in Gibbs energy i.e. $\Delta G = \Delta H - T\Delta S$ equation(A)

Where, ΔH is the enthalpy change and ΔS is the entropy change for the process.

o   This equation can also be written as:- $\Delta G^{(-)} = -RTlnK$ equation(1)

Where, K is the equilibrium constant of the 'reactant – product' system at the temperature, T. A negative ΔG implies a +ve K in equation (1).

o   Following conclusions can be made:-
o   When the value of ΔG is negative in equation (A), only then the reaction will proceed.
o   If reactants and products of two reactions are put together in a system and the net ΔG of the two possible reactions is –ve, the overall reaction will occur.
o   During reduction, the oxide of metal decomposes:

$M_xO(s)$ à xM (solid or liquid) + (1/2) O_2 (g)   Equation (2)

The reducing agent takes away the oxygen. Equation (2) is the reverse of the oxidation of the metal. And then, the $\Delta_f G^{(-)}$ value is written in the usual way: $xM(s \text{ or } l) + (½) O_2 (g) \rightarrow MxO(s)$ [$\Delta G^{(-)}_{(M, MxO)}$] equation (B)

o   If reduction is being carried according to equation(2), the oxidation of the reducing agent(e.g. C or CO) will be:-
   o $C(s) + (1/2) O_2(g)$ à CO (g) [$\Delta G^{(-)}_{(C,CO)}$]   equation (3)
   o $CO(s) + (1/2) O_2(g)$ à CO_2 (g) [$\Delta G^{(-)}_{(C,CO)}$] equation(4)
o   If carbon is taken, there may also be complete oxidation of the element to CO_2:
o $(1/2) C(s) + (1/2) O_2(g)$ à $(1/2) CO_2(g)$ [$(1/2) \Delta G_{(C,CO2)}$]   equation(5)
o   On subtracting equation (B) from one of the three equations (3, 4 or 5).
o $M_xO(s) + C(s) \rightarrow xM(s \text{ or } l) + CO(g)$
o $M_xO(s) + CO(g) \rightarrow xM(s \text{ or } l) + CO_2(g)$
o $M_xO(s) + (1/2) C(s) \rightarrow xM(s \text{ or } l) + (½) CO_2(g)$ equation(8)
o   These reactions describe the actual reduction of the metal oxide, M_x

Extraction of Iron from oxide

o   Oxide ores of iron, after concentration through calcination/roasting (to remove water, to decompose carbonates and to oxidise sulphides) are mixed with limestone and coke and fed into a Blast furnace from its top. In this case, the oxide is reduced to the metal.
o   One of the main reduction steps in this process is:
o $FeO(s) + C(s) \rightarrow Fe(s/l) + CO (g)$
o   Consider the above reaction as 2 simpler reactions, in One reduction of FeO takes place and in another C is being oxidised to CO:

- o   FeO(s) → Fe(s) +(½) O_2(g) [$\Delta G_{(FeO, Fe)}$] equation (C)
- o   C(s) + (1/2) O_2 (g) → CO (g) [$\Delta G_{(C, CO)}$]
- o   When both the reactions take place to yield the equation (8),

The net Gibbs energy change becomes:

$\Delta G_{(C, CO)} + \Delta G_{(FeO, Fe)} = \Delta_r G$ equation (9)

- o   The resultant reaction will take place if RHS of the equation (9) is negative.
- o   In $\Delta G^{(-)}$ vs T plot representing reaction by equation (C), the plot goes upward and that representing the change C→CO (C, CO) goes downward.
- o   At temperatures above 1073K (approx.),
- o   The (C, CO) line comes below the Fe, FeO line [$\Delta G_{(C, CO)} < \Delta G_{(Fe, FeO)}$].
- o   So in this range, coke will be reducing the FeO and will itself be oxidised to CO.

- o   In a similar way the reduction of Fe_3O_4 and Fe_2O_3 at relatively lower temperatures by CO can be explained on the basis of lower lying points of intersection of their curves with the CO, CO_2
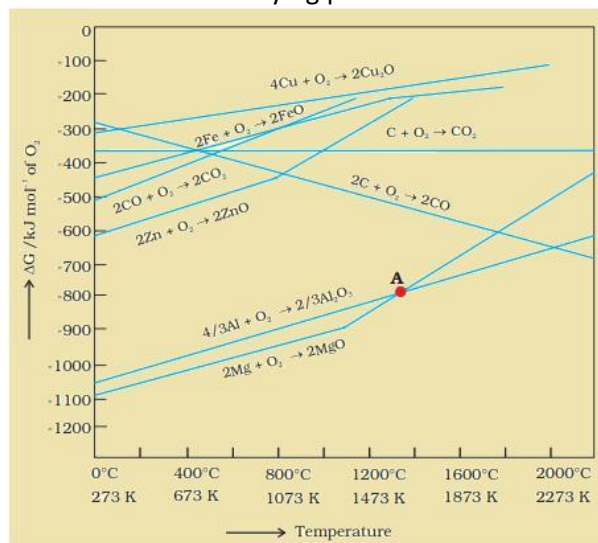
(Graph 1) Gibbs energy (ΔGV) vs T plots (schematic) for formation of some oxides (Ellingham diagram)

Blast Furnace

Blast Furance
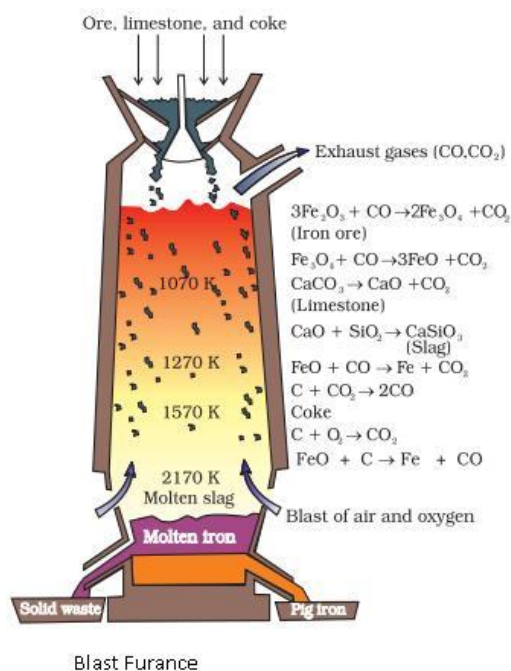
- o In the Blast furnace, reduction of iron oxides takes place in different temperature ranges.
- o Hot air is blown from the bottom of the furnace and coke is burnt to give temperature upto about 2200K in the lower portion itself.
- o The burning of coke therefore supplies most of the heat required in the process. The CO and heat moves to upper part of the furnace.
- o In upper part, the temperature is lower and the iron oxides (Fe_2O_3 and Fe_3O_4) coming from the top are reduced in steps to FeO.
- o Thus, the reduction reactions taking place in the lower temperature range and in the higher temperature range, depend on the points of corresponding intersections in the $\Delta_rG^{(-)}$ vs T plots.
- o Following are the reactions which are taking place:-
  - o At 500 – 800 K (lower temperature range in the blast furnace)–
    - o $3Fe_2O_3 + CO \rightarrow 2\,Fe_3O_4$
    - o $Fe_3O_4 + 4\,CO \rightarrow 3Fe + 4CO_2$
    - o $Fe_2O_3 + CO \rightarrow 2\,FeO + CO_2$

- o At 900 – 1500 K (higher temperature range in the blast furnace):
- o $C + CO_2 \rightarrow 2\,CO$
- o $FeO + CO \rightarrow Fe + CO_2$

Products formed in Blast Furnace
- o Limestone is also decomposed to CaO which removes silicate impurity of the ore as slag. The slag is in molten state and separates out from iron.
- o The iron obtained from Blast furnace contains about 4% carbon and some other impurities. This iron is known as **pig iron**.
- o **Cast iron** is different from pig iron and is made by melting pig iron with scrap iron and coke using hot air blast. It has slightly lower carbon content (about 3%) and is extremely hard and brittle.
- o **Wrought iron** or malleable iron is the purest form of commercial iron and is prepared from cast iron by oxidising impurities in a reverberatory furnace lined with haematite.

- o This haematite oxidises carbon to carbon monoxide:
  - o $Fe_2O_3 + 3\ C \rightarrow 2\ Fe + 3\ CO$
  - o Limestone is added as a flux and sulphur, silicon and phosphorus are oxidised and passed into the slag. The metal is removed and freed from the slag by passing through rollers.

Extraction of copper from cuprous oxide [copper [I] oxide]
- o Considering the Graph (1) the Cu_2O line is at the top.
- o So to reduce oxide ores of copper directly to the metal by heating with coke (both the lines of C, CO and C, CO_2 are at much lower positions in the graph particularly after 500 – 600K).
- o Most of the ores are sulphide and some may also contain iron. The sulphide ores
- o are roasted/smelted to give oxides:
- o $2Cu_2S + 3O2 \rightarrow 2Cu_2O + 2SO_2$
  - o The oxide can then be easily reduced to metallic copper using coke:
  - o $Cu_2O + C \rightarrow 2\ Cu + CO$
- o In actual process, the ore is heated in a reverberatory furnace after mixing with silica. In the furnace, iron oxide 'slags of' as iron silicate and copper is produced in the form of copper matte. This contains Cu_2S and FeS.
  - o $FeO + SiO_2 \rightarrow FeSiO_3$ (Slag)
- o Copper matte is then charged into silica lined convertor.
- o Some silica is also added and hot air blast is blown to convert the remaining
  - o FeS_2, FeO and Cu_2S/Cu_2O to the metallic copper.
    - o Following reactions take place:
      - o $2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$
      - o $FeO + SiO_2 \rightarrow FeSiO_3$ (6.38)
      - o $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$
      - o $2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$
  - o The solidified copper obtained has blistered appearance due to the evolution of SO_2 and so it is called blister copper.

Extraction of Zinc from Zinc Oxide
- o The reduction of zinc oxide is done using coke. The temperature in this case is higher than that in case of copper.
- o For the purpose of heating, the oxide is made into brickettes with coke and clay.
  - o $ZnO + C \rightarrow Zn + CO$ (where coke is the catalyst, and temperature is 673 K)
- o The metal is distilled off and collected by rapid chilling.

**Electrochemical Principles of Metallurgy**
- o In the reduction of a molten metal salt, electrolysis is done.
- o Consider the equation:-
  - o $\Delta G^{(0)} = -\ nE^{(-)}F$ equation (1)
  - o n= number of electrons and $E^{(-)}$ = electrode potential of redox couple formed in the system.
  - o More reactive metals have large negative values of the electrode potential.
  - o This implies their reduction is very difficult.
- o If the difference of two $E^{(-)}$ values corresponds to a positive $E^{(-)}$ and consequently negative $\Delta G^{(0)}$ in equation (1).
- o As a result then the less reactive metal will come out of the solution and the more reactive metal will go to the solution.

- o For example:- $Cu_2+ (aq) + Fe(s) \rightarrow Cu(s) + Fe_2+ (aq)$
- o In simple electrolysis, the Mn^+ ions are discharged at negative electrodes (cathodes) and deposited there. Sometimes a flux is added for making the molten mass more conducting.

Aluminium

- o In the metallurgy of aluminium, purified Al_2O_3 is mixed with Na_3AlF_6 or CaF_2 which lowers the melting point of the mix and brings conductivity.
- o The fused matrix is electrolysed.
- o Steel cathode and graphite anode are used. The graphite anode is useful here for reduction to the metal.
- o The overall reaction may be taken as:
  - o $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$
- o This process of electrolysis is widely known as Hall-Heroult process.
- o The electrolysis of the molten mass is carried out in an electrolytic cell using carbon electrodes. The oxygen liberated at anode reacts with the carbon of anode producing CO and CO_2.
- o This way for each kg of aluminium produced, about 0.5 kg of carbon anode is burnt away.
- o The electrolytic reactions are:
- o Cathode: $Al_3+ (melt) + 3e- \rightarrow Al(l)$
- o Anode: $C(s) + O_2- (melt) \rightarrow CO(g) + 2e^-$
- o $C(s) + 2O^{2-} (melt) \rightarrow CO_2 (g) + 4e^-$
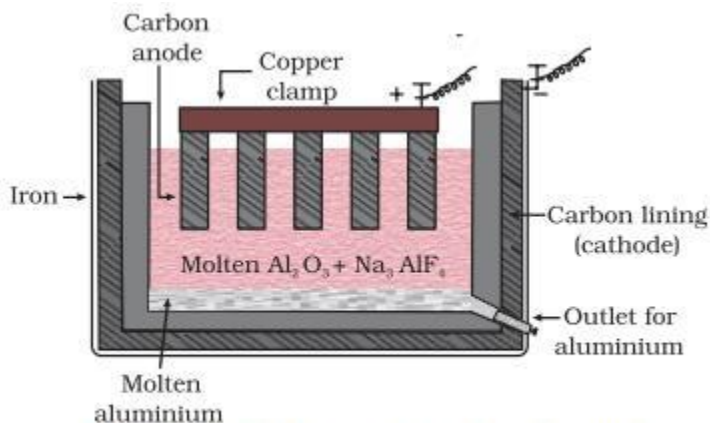
Electrolytic cell for the extraction of aluminium

Refining

- o A metal extracted by any method is usually contaminated with some impurity.
- o For obtaining metals of high purity, several techniques are used depending upon the differences in properties of the metal and the impurity.
- o Following are the methods used to refine the metals:-
- o Distillation
- o Liquation
- o Electrolysis
- o Zone refining
- o Vapour phase refining
- o Chromatographic methods

Distillation

- o This is very useful for low boiling metals like zinc and mercury. The impure metal is evaporated to obtain the pure metal as distillate.

(b) Liquation

- o In this method a low melting metal like tin can be made to flow on a sloping surface. In this way it is separated from higher melting impurities.

(c) Electrolytic Refining

- o In this method the impure metal is made to act as anode. A strip of the same metal in pure form is used as cathode.
- o They are put in a suitable electrolytic bath containing soluble salt of the same metal.
- o The more basic metal remains in the solution and the less basic ones go to the anode mud.
- o The reactions are:
  - o Anode: $M \rightarrow M^{n+} + n e^{-}$
  - o Cathode: $M^{n+} + n e^{-} \rightarrow M$
- o This method is used to refine Copper, Zinc etc.
  - o In case of copper refining-
  - o Anodes are of impure copper and pure copper strips are taken as cathode.
  - o The electrolyte is acidified solution of copper sulphate and the net result of electrolysis is the transfer of copper in pure form from the anode to the cathode:
  - o Anode: $Cu \rightarrow Cu^{2+} + 2 e^{-}$
  - o Cathode: $Cu_{2}+ + 2e^{-} \rightarrow Cu$
  - o Impurities from the blister copper deposit as anode mud which contains antimony, selenium, tellurium, silver, gold and platinum; recovery of these elements may meet the cost of refining.

(d) Zone refining

- o This method is based on the principle that the impurities are more soluble in the molten form as compared to the solid state of the metal.
- o A circular mobile heater is fixed at one end of a rod of the impure metal.
- o The molten zone moves along with the heater which is moved forward. As the heater moves forward, the pure metal crystallises out of the melt and the impurities pass on into the adjacent molten zone.
- o The process is repeated several times and the heater is moved in the same direction. At one end, impurities get concentrated.
- o This end is cut off. This method is very useful for producing semiconductor and other metals of very high purity, e.g., germanium, silicon, boron, gallium and indium.
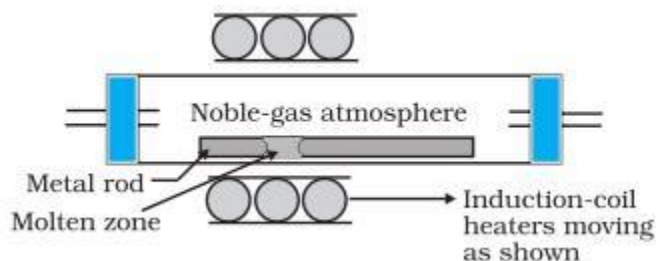
- o Vapour Phase Refining
- o The metal is converted into its volatile compound and collected elsewhere. It is then decomposed to give pure metal.
- o There are 2 requirements for this method:-
  - o The metal should form a volatile compound with an available reagent,
  - o The volatile compound should be easily decomposable, so that the recovery is easy.

- o For example: - Mond Process for Refining Nickel and van Arkel Method for Refining Zirconium or Titanium.
- o Chromatographic method
- o The principle of this method is that different components of a mixture are differently adsorbed on an adsorbent. The mixture is put in a liquid or gaseous medium which is moved through the adsorbent.
- o Different components are adsorbed at different levels on the column.
- o The adsorbed components are removed or eluted by using suitable solvents (eluant).
- o Depending upon the physical state of the moving medium and the adsorbent material and also on the process of passage of the moving medium, the chromatographic method is given the name.
- o The Al_2O_3 is prepared in a glass tube and the moving medium containing a solution of the components is in liquid form. This is an example of column chromatography.
- o There are several chromatographic techniques such as paper chromatography, column chromatography, gas chromatography, etc.
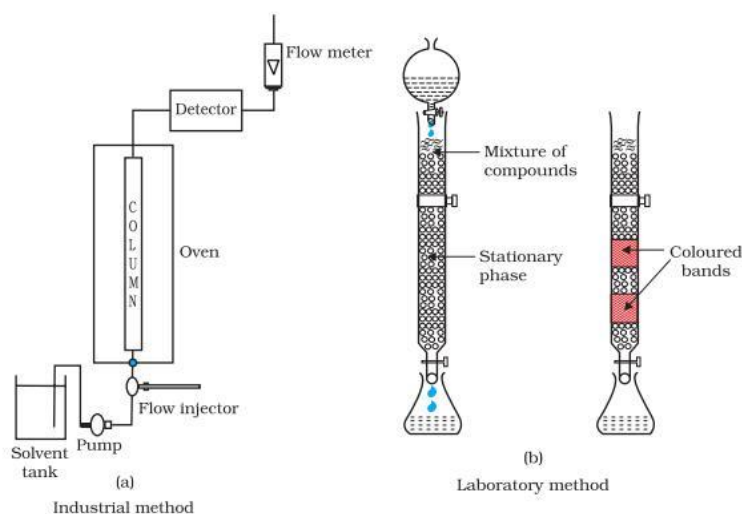

Diagram showing column chromatography

Uses of Aluminium, Copper, Zinc & Iron
Aluminium
1. Aluminium foils are used as wrappers for chocolates.
2. The fine dust of the metal is used in paints and lacquers.
3. Aluminium, being highly reactive, is also used in the extraction of chromium and manganese from their oxides. Wires of aluminium are used as electricity conductors.
4. Alloys containing aluminium, being light, are very useful.

Copper
1. Copper is used for making wires used in electrical industry and for water and steam pipes.
2. It is also used in several alloys that are rather tougher than the metal itself, e.g., brass (with zinc), bronze (with tin) and coinage alloy (with nickel).

Zinc
1. Zinc is used for galvanising iron. It is also used in large quantities in batteries, as a constituent of many alloys, e.g., brass, (Cu 60%, Zn 40%) and German silver (Cu 25-30%, Zn 25-30%, Ni 40–50%).
2. Zinc dust is used as a reducing agent in the manufacture of dye-stuffs, paints, etc.

Iron

1. <u>Cast iron</u>, which is the most important form of iron, is used for casting stoves, railway sleepers, gutter pipes, toys, etc. It is used in the manufacture of wrought iron and steel.
2. <u>Wrought iron</u> is used in making anchors, wires, bolts, chains and agricultural implements.
3. <u>Steel</u> finds a number of uses. Alloy steel is obtained when other metals are added to it.
4. <u>Nickel steel</u> is used for making cables, automobiles and aeroplane parts, pendulum, measuring tapes, chrome steel for cutting tools and crushing machines, and stainless steel for cycles, automobiles, utensils, pens, etc.