PRINCIPLES INVOLVED IN THE EXTRACTION OF ELEMENTS

Occurrence of Elements: Earth is the main source of various elements. Atmosphere, earth's crust and sea are the main source of elements. Atmosphere consists various gases like nitrogen, oxygen etc. Earth consists of metals in the form of minerals. Metal can be found either in the free state or in the combined form. Metals like gold, silver, platinum and bismuth are found in the free state whereas other metals are found in the form minerals which is combined form of metals. When mineral contains profitable amount of metal then it is known as ore.

Relative abundance of elements in earth's crust:

Elements	% in earth crust
Oxygen	46.60
Silicon	27.70
Aluminium	8.13
Iron	5.10
Calcium	3.63

Extraction of elements: Extraction of elements consists of following steps:

(1) ***Concentration of ore:*** In this step, the amount of desired element is increased by eliminating undesired substances. These undesired substances are known as **"Gangue".** In simple words we can say that ore consist of two parts, desired metal compound and gangue.

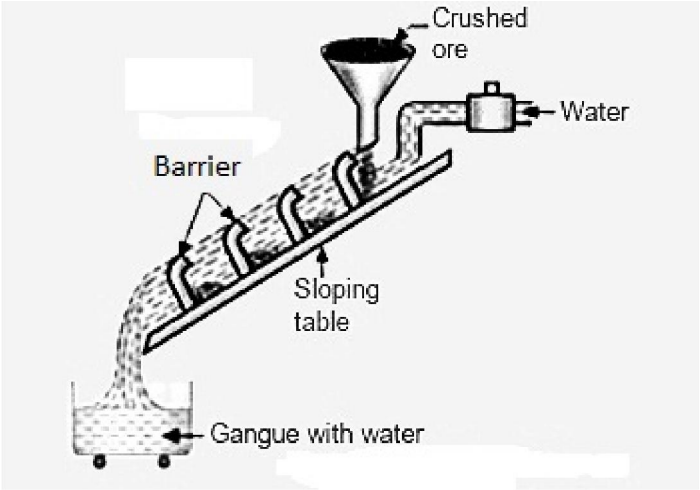
Ore = Desired metal compound + Gangue

Concentration methods are as follows:

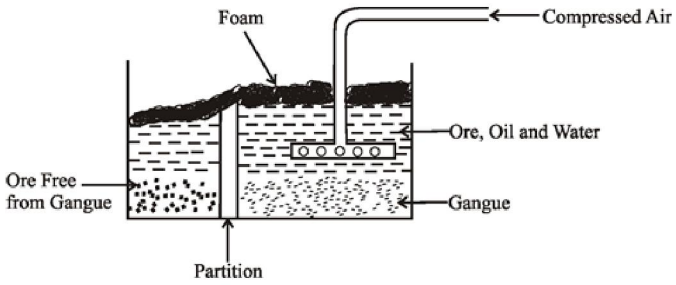
- **Hand Picking:** When impurities can be easily differentiated by naked eye, then it can be handpicked to separate these impurities from metal compound.

- **Gravity separation method:** This method is used when impurities have density difference with metal compound. It is applicable to ores of tin and lead. In this method a stream of water is flown on inclined table having hurdles. Crushed ore

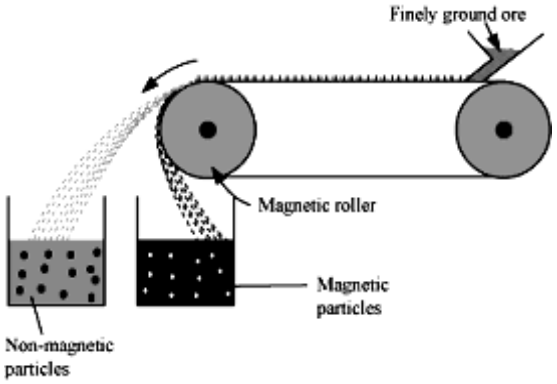
is kept on initial side of barrier and it is washed with water. The lighter particles are washed with the stream of water and heavier particles remain behind the hurdles.



- **<u>Froth floatation method:</u>** This method depends upon the relative interaction of impurities and metal compound with solvent like water. It depends on the wettability of mineral. In this method, finely ground ore is mixed with water and then small amount of pine oil is added to it. It will help to cause frothing. Then this mixture is agitated with air. As a result of this, froth bubbles are generated. This froth contains our desired metal compound and gangue material is left behind in the water. Sulphide ores are concentrated with this method.



- **<u>Magnetic concentration:</u>** when the impurities and metal compounds have different magnetic properties, then this method is used to concentrate the ore. In this method, finely ground ore is kept over a belt which moves on a pulley magnet. Due to attraction of pulley magnet, the magnetic compound falls near the pulley magnet whereas the non-magnetic substance falls away from the pulley magnet. By this way ore is concentrated. Generally iron ore is concentrated with the help of this method.



- **Leaching:** In this method, the finely ground ore is treated with a solvent or chemical which dissolves only the metal compound and not the impurities. Later on the desired metal compound can be regenerated with a suitable method. Solvent can either solubilise the metal compound or react with it. If solubilises the compound then it can be regenerated by simple evaporation of solvent.

(2) ***Conversion of concentrated ore into metal oxide:*** conversion of ore into metal oxide can be done by two methods. These methods are as follows:

- **Roasting:** In this method, the ore is heated with stream of air. This is generally done with the sulphide ores. This heating should be carried out at a temperature below the melting point of the ore. By heating in the presence of air, the sulphur and other volatile impurities are removed.

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

- **Calcination:** In this method, the ore is heated in absence of air. This is generally done with the carbonate ores. On heating the carbonate ore are decomposed into oxides and carbon dioxide is released. This is done to remove water or other volatile impurities from the ores.

$$CaCO_3 \longrightarrow CaO + CO_2$$

$$Al_2O_3.2H_2O \longrightarrow Al_2O_3 + 2H_2O$$

(3) **Conversion of metal oxide into metal oxide:** Once the metal oxides are obtained from the above mentioned processes, then these oxides are converted into metallic

from by the process of reduction. There are various reducing methods depending upon the position of metal in electrochemical series.

- The metal cation which occupies lower position in the electrochemical series can be easily reduced by addition of electron and can be converted into metallic form.
- The metal cation which occupies higher position in the electrochemical series cannot be easily reduced by addition of electron. These metal cations are reduced by electrolysis of their salts in fused state.

Various reduction methods are as follows:

- **Reduction by carbon:** In this method, the oxide is heated with carbon in form of coke. Temperature is kept higher than the melting point of metal.
  This method is used with those metals which do not form carbides with carbon.

$$ZnO + C \xrightarrow{\Delta} Zn + CO$$
$$PbO + C \xrightarrow{\Delta} Pb + CO$$
$$Cr_2O_3 + 3C \xrightarrow{\Delta} 2Cr + 3CO \text{ (Davill's Process)}$$

  In order to remove non-fusible impurities an additional substance is added to the mixture along with coke. **This substance is known as flux**. This process of heating the above mixture is known as smelting, based on the nature of impurities, the flux can be either acidic or basic flux. To remove a basic impurity, acidic flux is added or vice versa.

$$\underset{\text{Acidic Flux}}{SiO_2} + \underset{\text{Basic Impurity}}{FeO} \longrightarrow FeSiO_3$$

$$\underset{\text{Basic Flux}}{CaO} + \underset{\text{Acidic Impurity}}{SiO_2} \longrightarrow CaSiO_3$$

- **Reduction by Carbon monoxide:** In this method carbon monoxide is used to reduce metallic oxide.

$$Fe_2O_3 + 3CO \xrightarrow{\Delta} 2Fe + 3CO_2$$
$$NiO + CO \xrightarrow{\Delta} Ni + CO_2$$

- **Reduction by hydrogen:** In this method, hydrogen gas is used to reduce metallic oxide. Those metals which are less electropositive than hydrogen can be reduced by this method.

$$3Fe_2O_3 + 9H_2 \xrightarrow{\Delta} 6Fe + 9H_2O$$

- **Reduction by Aluminium(Gold Schmidt's aluminothermic Process):**
In this method metal oxides are ignited with Al-powder in fire clay crucible. This mixture of metal oxide and al-powder is known as thermite. The crucible is enclosed by sand which prevents the loss of heat. A strip of magnesium ribbon is kept in the ignition mixture (Na_2O_2 + Mg Powder) which is further kept in the thermite. This ribbon helps in the ignition of mixture. Reaction between Na_2O_2 and Mg Powder generates a large amount of heat by following reaction:

$$Mg + Na_2O_2 \longrightarrow Na_2O + MgO + Heat$$

This heat helps in the reaction between metal oxide and Aluminium powder.

$$Cr_2O_3 + 2Al \longrightarrow 2Cr + Al_2O_3 + Heat$$

Due to excess heat of these reactions, the metal is obtained in the molten state.

- **Electrolytic methods:** Alkali metals and alkaline earth metals are reduced by this method. These metals are highly reactive. So when above methods are used they react either with product or the reactant to from some undesired substances. These metals can be obtained by electrolysis of their molten salts.

$$CaCl_2 \rightleftharpoons Ca^{2+} + 2Cl^-$$

At Cathode: $Ca^{2+} + 2e^- \longrightarrow Ca$

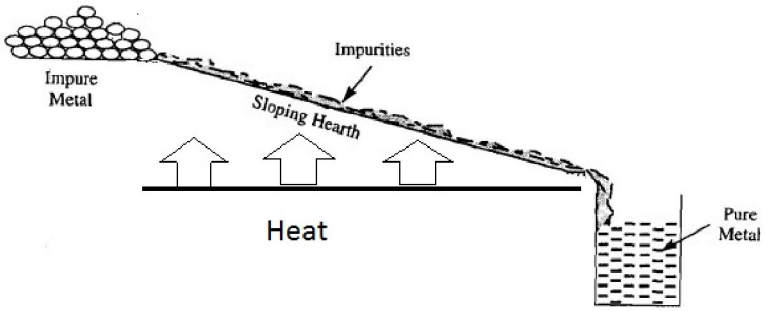
At Anode: $2Cl^- \longrightarrow Cl_2 + 2e^-$

Apart from the above reduction methods, various other methods are also used. Such as reduction by Na-Metal, by K-Metal and by Ca metal etc.

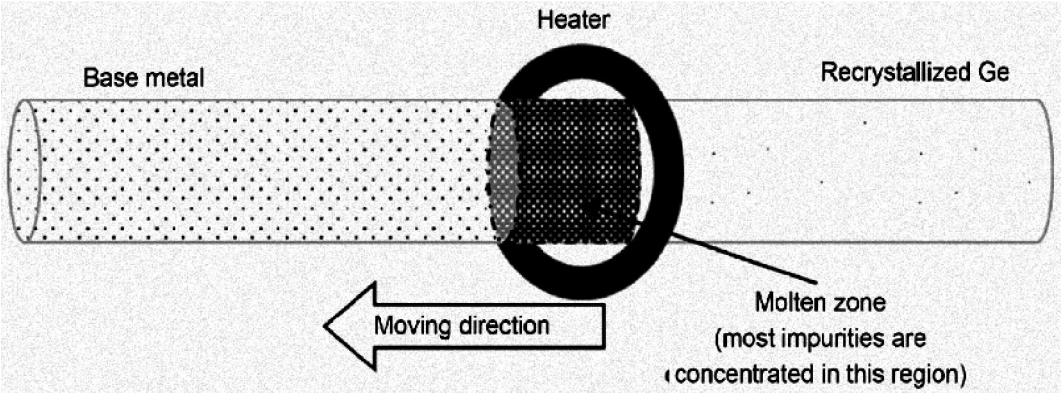
(4) Purification or refining of impure metals: Metals obtained from the above mentioned processes contains various impurities. Therefore metals needs to be

refined by some processes. Process of purification depends upon the nature of metal. Methods of purification are as follows:

- **Liquation:** When metal has lower melting point than the impurities present, then this method is used. In this method, metal is placed on the sloping hearth which is heated just above the melting point of metal. The metal melts and flows down the slope whereas the impurities remain on the hearth. This method is used to purify Sn and Zn metal.



- **Zone refining Method:** this method is also known as fractional crystallisation method. This is used when metal of very high purity is required. This method is based on the principle that an impure metal on gradual cooling will be converted into crystal. Whereas the impurities will be left in the molten metal. In this method the metal which is to be purified is taken in a tube. Then a heating filament is fitted around the tube and it is moved along the length of the tube. When it is present in a region, it melts the metal of that region. As it is moved, the molten metal of previous region cools down and converted into the crystals. The impurities of this region move into the molten region of filament. This process is repeated along the whole length of tube. At the end of the process, we get region of pure metal at one side of tube and region of impurities of on other side of tube.



- **<u>Van Arkel De Boer's process:</u>** This method is also known as iodine refining process. In this method the metal is converted into the highly unstable volatile compound, which further decomposes to give pure metal. The metal is heated with iodine to form metal iodide. The metal iodide decomposes to from metal and iodine. It is used to purify Ti, Zr, V and Th metal.

  $Ti\ (impure) + 2I_2 \longrightarrow TiI_4 \longrightarrow Ti(Pure) + 2I_2$

- **<u>Amalgamation Process:</u>** This method can be used for the purification of Silver and gold. When Ag and Au react with Hg and from amalgam then this amalgam is distilled in iron retort. Hg is more volatile, is distilled off and pure Ag or Au is left behind.

- **<u>Electrolytic Methods:</u>** Metals can also be refined by electrolysis of their salts. The impure metal is made as the anode and the pure metal is made as the cathode. During electrolysis, the pure metal generated due to reduction, is deposited on the cathode. Whereas the impurities either go into the solution or remain on the anode.

Apart from the above mentioned processes, various other methods are used for the refining of metals. These methods are as follows:

- Poling
- Oxidation
- Distillation