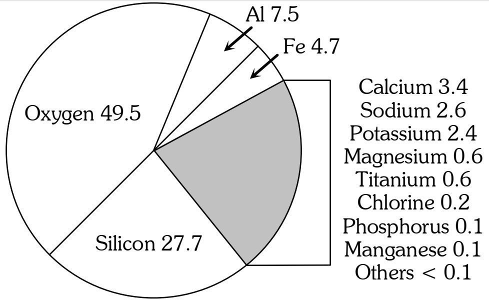
General Principals and Processes of Isolations of metals

All the materials found in the earth are composed of elements. There are about 112 elements known which constitute the entire matter on the earth. Therefore, the elements are regarded as the building blocks of the universe. These are distributed in all the three main parts of the earth; atmosphere and lithosphere. Among these, lithosphere constitutes the main source of most of the elements. The elements have been broadly divided into metals and non-metals on the basis of their physical and chemical properties. Entire distribution of sixteen most abundant elements in the earth's crust and their percentages by weight are shown in figure.



Distribution of elements in the earth's crust

Occurance of Metals .

Element which have low chemical reactivity generally occur ***native*** or ***free*** or ***metallic*** state. e.g. Au, Pt, noble gas etc**.** Element which are chemically reactive, generally occur in the ***combined state***. e.g. halogens, chalcogens etc. The natural materials in which the metals occur in the earth are called ***minerals***. The mineral from which the metal is conveniently and economically extracted is called an ***ore***. *All the ores are minerals but all minerals cannot be ores.* Ores may be divided into four groups,

(1) **Native ores :** These ores contain metals in free state, e.g., silver, gold, platinum, mercury, copper, etc. Sometimes lumpes of pure metals are also found. These are termed ***nuggets***. Iron is found in free state as meteroites which also have 20 to 30% nickel.

(2) **Sulphurised and arsenical ores :** These ores consist of sulphides and arsenides in simple and complex forms of metals.

(3) **Oxidised ores :** In these ores, metals are present as their oxides or oxysalts such as cabonates, nitrates, sulphates, phosphates, silicates, etc.

(4) **Halide ores :** Metallic halides are very few in nature. Chlorides are most common e.g., Common salt, Horn silver, Fluorospar, Cryolite.

Metals in Biology .

Metals are also found in living organisms, e.g.,

(1) Magnesium is found in chlorophyll.

(2) Potassium is present in plant roots.

(3) Manganese, Iron and copper are present in chloroplast.

(4) Zinc is present in eyes of cats and cows.

(5) Iron is present in haemoglobin.

(6) Calcium is present in bones.

(7) Vanadium is present in cucumbers.

(8) Chromium is present in prown.

Mineral Wealth of India .

Minerals are the gifts of nature. They occur at definite spots. They are needed both for plants and animal life. The development of Saudi Arabia is a dramatic story of how minerals transform a barren waste into a thriving land. Some of the minerals which occur in India are given below.

(1) **Gold :** India is a minor producer of gold and her production comes from Hutte and Kolar gold field in Karnataka. It also occurs in the alluvial sands of Ganges, Irrawaty and Swarnrekha. India stands the eight position among the gold producing countries of the world. India produces 2824 kg of gold in 1975.

(2) **Copper :** It is formed in Singhbhum and Hazaribagh district in Bihar, Agnigundala in Andra Pradesh, Malanjkh in Madhya Pradesh and Khetri in Rajasthan. Copper production in India was 25,000 tons in 1976.

(3) **Iron :** It occurs as haematite, Fe_2O_3. The major iron producing states in India are Orissa, Bihar, Madhya Pradesh, Mysore and Goa. The other iron producing states of minor importance are Maharashtra, Andhra Pradesh, Rajasthan, Tamil Nadu, Utter Pradesh, Punjab and Jammu and Kashmir. Annual product of iron ore in the country is about 22 million metric tons.

(4) **Aluminium :** It is, one of the most important metals in the modern industrial era. Its chief minerals bauxite and corundum are found in Rewa, Bhopal, Orissa, Bihar, Tamil Nadu, Saurashtra and Kashmir. Its production in the country in 1975 was 175,000 metric tons.

(5) **Manganese :** India is a important producer of the best quality of manganese in the world. Our production of its ore in 1975 was 134–136 metric tons. It occurs in Madhya Pradesh, Maharastra, Madras, Mysore, Andhra Pradesh, Bihar, Rajasthan etc.

(6) **Tin :** It is an important non ferrous metal. It is found in Bihar, Orissa and Rajasthan.

(7) **Chromium :** The metal occurs as chromate or chrome iron ore in Mysore, Bihar, Orissa and Maharashtra.

(8) **Lead :** Its sulphide ore galena occurs in Bihar, Madhya Pradesh and Rajasthan. India produced 5200 tons of lead in 1975.

(9) **Lime Stone :** It occurs in Satna, Katni and Rohtasgarh. Marble is formed in Jaipur and Madhya Pradesh.

(10) **Mica :** India produces about 80% of world's mica production. The major mica producing states in India are Bihar, Andhra Pradesh and Rajasthan. Minor producing states are Tamil Nadu, West Bengal and Madhya Pradesh. The Bihar mica belts extends for a distance of about 160 km. passing through Hazaribagh district.

(11) **Thorium :** It occurs in monazite sands in Travancore. India enjoys a sole monopoly in this mineral.

Extraction of Metals: Metallurgy.

The extraction of a pure metal from its ore is called ***metallurgy.*** In order to extract the metal from ores, several physical and chemical methods are used. The method used depending upon chemical properties and nature of the ore from which it is to be extracted. It involves four main steps,

(1) Crushing and grinding of the ore.

(2) Concentration or dressing of the ore.

(3) Reduction to free metal.

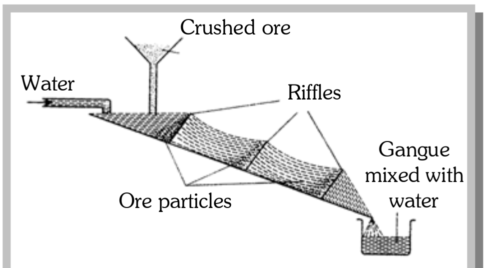
(4) Purification or refining of the metal.

(1) **Crushing and grinding of the ore :** Those ores occur in nature as huge lumps. They are broken to small pieces with the help of *crushers or grinders*. These pieces are then reduced to fine powder with the help of a ***ball mill or stamp mill.*** This process is called ***pulverisation.***

(2) **Concentration or dressing of the ore :** The ore are usually obtained from the ground and therefore contained large amount of unwanted impurities, e.g., earthing particles, rocky matter, sand, limestone etc. These impurities are known collectively as ***gangue*** or ***matrix***. It is essential to separate the large bulk of these impurities from the ore to avoid bulk handling and in subsequent fuel costs. The removal of these impurities from the ores is known as ***concentration***. The concentration is done by physical as well as chemical methods.

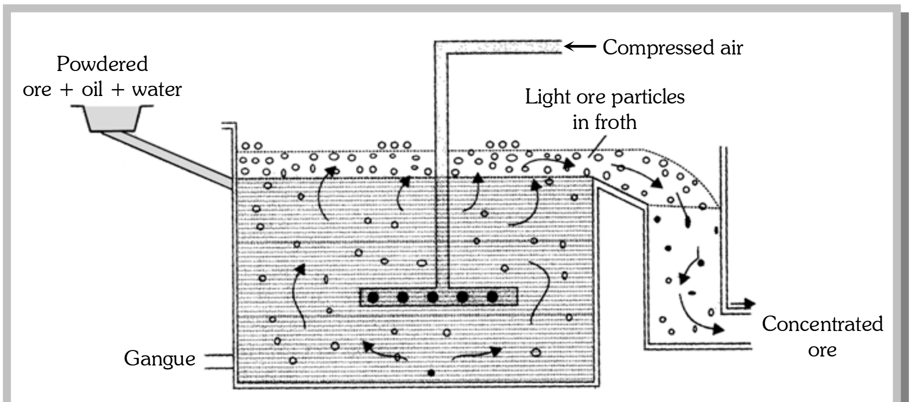
Physical Methods

(i) ***Gravity Separation or levigation*** **:** This process of concentration is based on the difference in the specific gravity of the ore and gangue. The sieved ore is either subjected to dry centrifugal separation or is placed in big shallow tanks in which a strong current of water blows. Heavy ore particles settle down to the bottom of the tanks while lighter gangue particles are carried away by the current of water. The process removes most of the soluble and insoluble impurities. For this purpose wilfley table and hydraulic classifier are widely used. The method is particularly suitable for heavy oxide and carbonate ores like *Cassiterite* (SnO_2) and haematite.



The Wilfley table

(ii) ***Froth floatation process*** **:** In some cases for example, sulphides ores of copper, zinc and lead concentration is brought by this method. In this method advantage is taken of the preferential wetting of the ore by an oil. The finely ground ore is taken in a tank containing water and 1% of pine oil or terpentine oil. A strong current of air is blown through the suspension, producing a heavy froth or foam on the surface. The metal sulphide is wetted by the oil but the gangues is not and the sulphide-oil mixture is carried to the surface by films of oil The froth is skimmed off, the gangue settles down on the bottom or remains underneath the froth. By this floation method it is possible to concentrate over 90% of a sulphite ore to 1/10 of its original bulk.



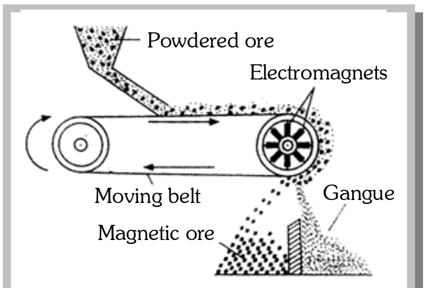
Froth floatation process

Note : ✹ Pine oil acts as *froth* since it forms a stable froth with the ore particles.

✹ In the floatation process, ethyl xanthate and potassium ethyl xanthate are also used which act as *Collectors*. These attach themselves to mineral particles by polar group which become water repellent and passed on into the froth.

Activators and Depressants **:** During the floatation process of some ores, these substances are added which activate or depress the floatation property of the minerals and thus help in the separation of minerals present in the ore. For instance, galena (PbS) is usually associated with sphalerite (ZnS) and pyrites (FeS_2). Concentration of galena is carried out by passing potassium ethyl xanthate (*Collector*) alongwith sodium cynamide and alkali (*depressants*) where by the floatation property of ZnS and FeS_2 is depressed. Mainly PbS passes into the froth when air current in flown in, which is collected. After PbS is removed with the froth, same $CuSO_4$ (activator) is added and air is blown. The floatation property of ZnS is increased which is now removed with the froth. The slurry is acidified and process is repeated when FeS_2 passed into the froth and is collected.

(iii) ***Electromagnetic separation*** **:** If the mineral and not gangue is attracted by a magnet, it can be concentrated by magnetic separation. For example chromite ore, $FeCr_2O_4$ being magnetic can be separated from non–magnetic silicons impurities by this method. Sometimes two minerals occur together, in which one happens to be magnetic. By magnetic separation method the nonmagnetic minerals is separated from the magnetic mineral. For example tin–stone or cassiterite, SnO_2 (non-magnetic) containing wolfram, $FeWO_4$ (magnetic) is separated by this method. In this method a thin layer of finely ground ore is spread over a rubber belt carried over a pulley in a magnetic field. The gangue particles or the particles of non–magnetic mineral fall off as the belt becomes vertical, and the magnetic particles collect.



Electromagnetic separation

Chemical methods

(i) ***Calcination*** **:** In this process the concentrated ore is heated in a suitable furnace generally in reveratory furnace much below its melting point in absence of air. As a result of which the ore dries up and moisture and volatile impurities are driven off and carbonates are converted into oxides and the ore becomes porous. For example,

$$Al_2O_3.2H_2O \rightarrow Al_2O_3 + 2H_2O \quad ; \quad 2Fe_2O_3.3H_2O \rightarrow 2Fe_2O_3 + 6H_2O$$

$$ZnCO_3 \rightarrow ZnO + CO_2 \quad ; \quad CaCO_3 \rightarrow CaO + CO_2 \quad ; \quad CuCO_3.Cu(OH)_2 \rightarrow 2CuO + CO_2 + H_2O$$

(ii) ***Roasting*** **:** The process of heating the ores strongly in presence of air with or without certain substances, below its melting point is termed as roasting. It differs from calcination in the respect that heating is done in presence of air and at a higher temperature. In this process the impurities of sulphur and arsenic etc. are volatilized away as oxides and the ore is converted into oxide. For example zinc oxide is formed by the oxidation of zinc blende, $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

(iii) ***Leaching*** **:** It involves the treatment of the ore with a suitable reagent as to make it soluble while impurities remain insoluble. The ore is recovered from the solution by suitable chemical method. For example, the chief ore of aluminium, bauxite ($Al_2O_3.2H_2O$) contains varying amounts of ferric oxides, titanium oxide and silica. Since alumina is amphoteric, it can be separated from the other two oxides. Finely powdered bauxite is digested with caustic soda solution at 150–170°C under pressure for some hours. Alumina dissolves forming soluble sodium aluminate.

$$Al_2O_3.\ 2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$$

The impurities remain unaffected and separated as insoluble red mud which is filtered off. The filtrate is diluted and some freshly precipitated aluminium hydroxide is added when $Al(OH)_3$ is precipitated as follows,

$$NaAlO_2 + 2H_2O \rightarrow NaOH + Al(OH)_3$$

The precipitated hydroxide is filtered off and calcified to get highly pure aluminium oxide (alumina).

$$2Al(OH)_3 \xrightarrow{\text{calcination}} Al_2O_3 + 3H_2O$$

Gold and silver are also extracted from their native ores by Leaching (Mac-Arthur forest cyanide process).

(3) **Reduction to free metal :** Some of the methods commonly used to get free metal from the concentrated ore are given below,

(i) ***Smelting*** **:** The process of extracting a metal in the state of fusion is called ***smelting***. In this process the ore is mixed with carbon, obtained after the above reactions and heated in suitable furnace. A suitable *flux* is added during the operation to convert the non–fusible gangue to fusible slag. The metallic oxide is reduced by carbon and the metal may be obtained in the molten state or as vapours which are condensed. Metals like tin, zinc or lead are obtained by this process.

$$SnO_2 + 2C \rightarrow Sn + 2CO \;;\; ZnO + C \rightarrow Zn + CO \;;\; Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

Flux and slag : Flux is a substance that is added during smelting to convert infusible silicons or earthy impurities into fusible material known as slag. Impurities + Flux = Slag. The slag is immiscible with the metal and has a low melting point and density. The slag floats on the metal and protects it from oxidation. It is removed from the furnance through the slag hole. If the impurities in the ore are acidic (SiO_2) in nature, a basic flux e.g., CaO, MgO, FeO etc. are added ; and if the impurities are basic (CaO, FeO, etc.) then on acidic flux (SiO_2) is used. The gangue or matrix present in the ore is refractory or non–fusible in nature but it reacts with the flux forming fusible slag which does not mix with the molten metal and forms the upper layer. Slag are usually silicates.

$$\underset{\text{Flux}}{CaO} + \underset{\text{Impurities}}{SiO_2} \rightarrow \underset{\text{Slag}}{CaSiO_3} \;;\; \underset{\text{Impurities}}{SiO_2} + FeO \rightarrow \underset{\text{Slag}}{FeSiO_3}$$

(ii) ***Reduction by Aluminium*** (Gold-schmidt alumino thermic process) **:** The process of reduction is used in the case of those oxides which can not be easily reduced by carbon. In this process, metallic oxides ore are mixed with aluminium powder commonly called as thermite and placed in a steel crucible lined inside with a refractory material and ignited by magnesium ribon. By the use of this process a number of metals such as chromium and manganese are obtained on a commercial scale in highly pure state.

$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr \;;\; 3\,MnO_2 + 4Al \rightarrow 2Al_2O_3 + 3Mn$$

Large amount of heat energy is released during reduction, which fuses both the alumina and the metal.

(iii) ***Self reduction process* :** This process is also called autoreduction process or air reduction process. The sulphide ores of less electropositive metals like $Hg, Pb, Cu,$ etc., are heated in air as to convert part of the ore into oxide or sulphate which then reacts with the remaining sulphide ore to give the metal and sulphur dioxide. No external reducing agent is used in this process.

(iv) ***Electrolytic reduction process* :** This process is used in the extraction of the alkali and alkaline earth metals, zinc and aluminium. The material from which a metal to be obtained is first smelted by heating and then electrolysed. Sometimes, some other salt is mixed to lower the melting point of the substance taken. For example,

$$NaCl \xrightleftharpoons{\text{(electrolysis)}} Na^+ + Cl^-$$

At anode (Oxidation) : $Cl^- \xrightarrow{-e^-} Cl \;;\; Cl + Cl \rightarrow Cl_2,$ At cathode (Reduction) : $Na^+ + e^- \rightarrow Na$

(v) ***Precipitation or metal displacement method*** (Hydrometallurgy) **:** This method is used for extraction of metals such as cadmium, copper, gold and silver. A metal having higher electrode potential is added into the solution of a metal of lower electrode potential with the result that the latter is displaced or precipitated.

$$CuSO_4 + Fe \rightarrow Cu + FeSO_4 \;;\; CdSO_4 + Zn \rightarrow Cd + ZnSO_4$$

$$2K[Ag(CN)_2] + Zn \rightarrow 2Ag + K_2[Zn(CN)_4] \;;\; 2K[Au(CN)_2] + Zn \rightarrow 2Au + K_2[Zn(CN)_4]$$

(vi) ***Amalgamation process* :** This method is used for the extraction of noble metals like gold, silver, etc., from the native ores. the finely powdered ore is brought in contact with mercury which combines with the particles of the metal present in the ore and form amalgam. The metal recovered from the amalgam by subjecting it to distillation, where the mercury distills over leaving behind the metal.

(4) **Purification or refining of metals :** Metals obtained as above are usually impure and need purification. Some of the methods used in the refining of metals are given below,

(i) ***By poling*** **:** The molten metals is stirred with green wood poles. Wood at the high temperature of the molten metals form hydrocarbons like methane which being about the reduction of any oxide present in the metal e.g., copper oxide present in the blister copper. In the case of the tin the impurities are oxidised and float on the molten metal as scum which is removed.

(ii) ***By cupellation*** **:** In this method the impure metal is heated in a blast of air when impurities are oxidised and blown away. For example, when impure silver is heated in air, lead present in it is oxidised to litharge (PbO) and blown away leaving a shining of silver.

(iii) ***By liquation*** **:** This process is used for refining easily fusible metals like lead and tin. The impure metal is heated on the slopy hearth of a reverberatory furnace. The metal melts and flows down leaving the impurities.

(iv) ***By distillation*** **:** Some metals have very low melting point and soon vaporize on behind heating, while the associated impurities remains in the solid state. Zinc, mercury and arsenic are purified by this method. Vacum distillation gives very pure product and is used in the refining of the metals of IA and IIA Groups.

(v) ***By fractional distillation*** **:** This process is applied for the separation of cadmium from zinc. In the metallurgy of zinc, the metal is invariably associated with cadmium. The impure zinc is mixed with powdered coke and heated when the first portion of the condensate contain cadmium while zinc is obtained in the subsequent portions.

(vi) ***By thermal dissociation*** **:** In this process the metal is first converted into some compound which is then decomposed into pure metal by heating. For example, impure nickel is heated with carbon monoxide at 60°C to form nickel carbonyl $Ni(CO)_4$ which is then decomposed at higher temperature, 150-180°C to give very pure nickel. Sometimes iron is also purified by this method.

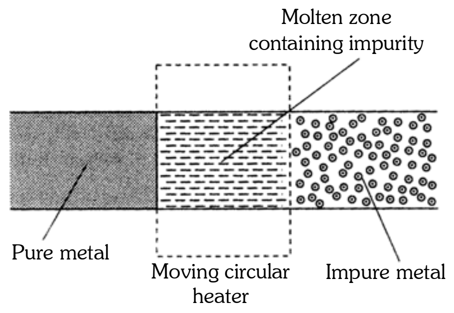
(vii) ***By Electrolytic refining*** **:** Most of the metals such as copper, silver, gold, zinc, nickel, and chromium are refined electrolytically. The impure metal is made the anode and a thin sheet of the pure metal the cathode in a suitable electrolytic bath. On passing current the metal from the anode passes in the solution and pure metal from the electrolyte is deposited on the cathode. The electrolyte used in the bath is usually a complex salt of the metal to enable the smooth deposition of pure metal on the cathode.

(viii) ***Special methods***

(a) *Mond's process* : Nickel is purified by this method. Impure nickel is treated with carbon monoxide at 60-80°C when volatile compound, nickel carbonyl, is formed. Nickel carbonyl decomposes at 180°C to form pure nickel and carbon monoxide which can again be used.

(b) *Van Arkel process* : This methods is generally applied for obtaining ultrapure metals. The impure metal is converted into a volatile compound while the impurities are not affected. The volatile compound is then decomposed electrically to get the pure metal. Ti, Zr, Hf, Si, etc., have been refined by this method.

(c) *Zone refining or fractional crystallisation* : Elements such as Si, Ge, Ga, etc., which are used as semiconductors are refined by this



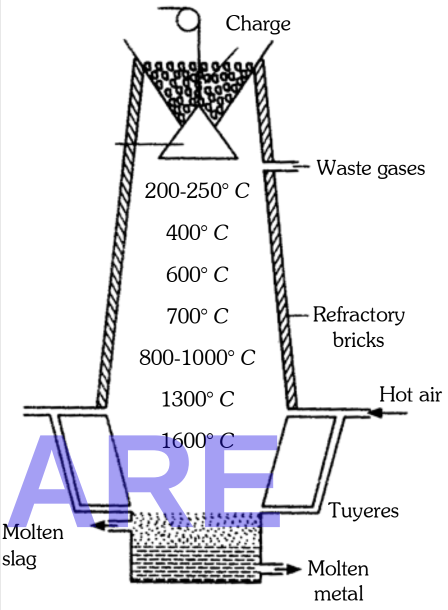
Zone refining of metals

method. Highly pure metals are obtained. The method is based on the difference in solubility of impurities in molten and solid state of the metals. A movable heater is fitted around a rod of the metal. The heater is slowly moved across the rod. The metal melts at the point of heating and as the heater moves on from one end of the rod to the other end, the pure metal crystallises while the impurities pass on the adjacent melted zone.

Furnaces.

In the extraction of metal different types of furnaces are used. Each furnace has its own characteristics. Some principal furnaces have been described below,

(1) **Blast furnace :** It is a special type of tall cylindrical furnace, about 100 feet high with a diameter of 15-28 feet. It is made of steel sheets lined inside with fire-proof bricks. The charge is added through a cup and cone arrangement at the top. At the upper part of the furnace there is a hole for the escape of the waste gases of the furnace. There are two outlets in the hearth of the furnace, one for tapping the molten metal and the other above it for the slag. The waste gases are heated and a hot air blast under pressure is blown into the furnace by means of bellows or fans through water cooled nozzles ortuyers. The temperature of the furnace varies from 250°C. to 1500°C. Thus the charge descends slowly into zone of increasing temperatures. The blast furnace is used for the extraction of metal like copper and iron.



Blast Furnace

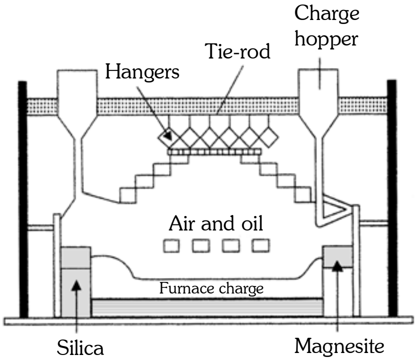
(2) **Reverberatory Furnace :** In this furnace fuel burns in a separate part and does not mix with the charge. The furnace may be divided into 3 parts,

(i) ***Fire Grate*** : It is on one side where the fuel burns.

(ii) ***Flue or Chimney* :** It is on the other side of the fire grate. The waste gases escape through it.

(iii) ***Hearth* :** It is the middle part of the furnace where the charge is heated with the flames and hot gases.

The material to be heated is placed on the hearth or bed of the furnace and is heated by the hot gases or flames produced by the burning of fuel. The waste gases escape out of the chimney. Since the fuel does not come in contact with the charge, the furnace is very suitable for calcination and roasting and is employed for both oxidising and reducing purposes. For oxidation, the material is heated by the current of hot air while for reduction the material is mixed with coke and heated. The furnace find wide application in the extractive metallurgy.



Modern reverberatory furnace

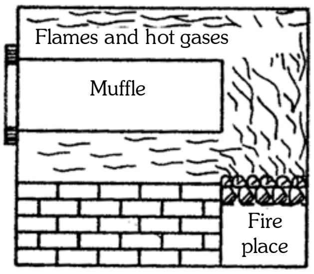
(3) **Electric Furnace :** The fuel burnt furnaces described in this chapter produce temperature in the range of 1000-1500°C. Although these furnaces have the great utility in the extraction of metals yet these are unsuitable where higher temperatures are needed. One commonly used electric furnace is Heroult's furnace shown in fig. It consists of a steel shell lined inside with dolomite or magnesite. It is provided with movable water jacketed

electrodes suspended from the roof or from the sides. Heat is generated by striking an arc between the electrodes, thereby, a temperature of over 3000°C may be reached. The charge melts and the impurities e.g., Si, Mn, P and S etc. present in the ore combine with the basic lining to form slag, which is free from sulphur or gas bubbles. Steel of very fine quality is prepared by this method. Electric furnaces are largely used where,

(i) Cheap power supply is available. (ii) High temperature are required. (iii) Pure product are required.

As such they find wide applicability in a number of industries such as metallurgy, ceramices plastics chemical and also in the research laboratories. These furnaces are easily operated and involve the problem of the storage of fuel and disposal of fuel waste.

(4) **Muffle Furnace :** In this furnace the material to be heated does not come in the contact with the fuel or flames. A muffle is a chamber made of refractory material and is surrounded by flames and hot gases on all sides. The products of combustion are removed through a door provided in the furnace. Muffle furnace is used for the extraction of zinc, preparation of red lead, Pb_3O_4 and for testing the purity of precious metals like silver and gold. In an electric muffle furnace the chamber is surrounded by resistance coils.



Muffle furnace

(5) **Bessemer Converter :** A Bassemer converter is a pear–shaped 10 or more feet high, open at the top, lined with a refractory material such as silica or magnesia which also acts as a flux. The converter is mounted on trunnions, so that it can be tilted to collect the products formed. There is an arrangement of introducing a hot blast of air from a number of small openings in the bottom of the furnace. The converter is used mostly for manufacturing of copper of steel from pig iron. Passing a current of hot air into the molten metal taken in the converter, the impurities are oxidised and escaped as gases or from slag. The Bessemer process is rapid one and does not take more than 15 minutes in the production of one bath.

(6) **Regenerative Furnace :** These are furnaces in which the heat of the gases escaping out from the chimney is utilized. Most of the furnaces particularly blast furnaces are fitted up with regenerated system which means an economy of the fuel. A flowing column of air is heated by the hot flue gases, it is then brought back to the fire and returned to the furnace. This furnace is largely used in the production of steel.

Refractory materials.

The materials which can withstand very high temperatures without melting or becoming soft are known as refractory materials. These are not affected by slags formed during the extraction of metals. These are used in the form of bricks for the internal linings of furnaces. Refractory materials used are of three types,

(1) **Acid refractories :** Silica, quartz, silicious sand stones, etc., are the examples.

(2) **Basic refractories :** Lime, dolomite, magnesite, etc., are the examples.

(3) **Neutral refractories :** Graphite, chromite, bone ash, etc., are the examples.

Silica $(92\% \ SiO_2, 2.7\% \ Al_2O_3)$ and quartz, can tolerate temperatures upto about 1750°C, bauxite upto 1800°C, alumina upto 2000°C and magnesite, chromite, etc., upto 2200°C. Some carbides such as silicon carbide is used as refractory for special purposes.

Alloys.

A metallic product containing two or more metals or sometimes one of the ingredients a non–metal provided that the mixture is homogenous and possesses metallic properties, is known as an alloy. Alloys are usually prepared by melting two or more metals together in the proportions and then allowing the melting to solidify. If one of the metals is mercury the alloy is known as ***amalgam***.

Alloys are prepared with a view to impart some desirable properties which the individual metals do not possess. These are,

(1) **Change in the chemical reactivity :** Sodium acts vigorously with water, but Na–Hg amalgam reacts slowly to suit the requirement of a number of chemical reactions.

(2) **Hardness :** Silver, gold and soft metals but become hard when alloyed with copper.

(3) **Melting Points :** Melting points of an alloy may be higher or lower than any of its components. Wood-metal, which is an alloy of Bi, Pb, Sn and Cd fuses at 60.5°C., while none of these metals fuses at this low temperature.

(4) **Change of colour :** Aluminium bronze is an alloy of aluminium and copper. It is of golden, yellow colour and is used in making decoration articles, jewellery and coins while the colour of aluminium is white and that of copper is red.

(5) **Corrosion resistance :** Iron gets corroded soon whereas stainless Steel, an alloy of iron and chromium, resists corrosion.

(6) **Casting :** An alloy of lead and antimony is known as *type metal* is used for casting type required in printing works.

Alloys of Al

Alloy	Percentage		Important Properties	Uses
Aluminium bronze	Al Cu	95% 5%	Light, strong alloy with golden lustre, resistant to corrosion	Coins, utensils, jewellary picture frames etc.
Magnalium	Al Mg	95% 5%	Light, tough and strong	Light instruments, balance beam, pressure cookers etc.
Duralumin	Al Cu Mg Mn	95% 4% 0.5% 0.5%	Light, tough, ductile, resistant to corrosive action	Making aeroplanes automobile parts pressure cookers etc.

Alloys of Ag

Alloy	Percentage composition	Uses
Coinage silver	Ag = 90, Cu = 10	For making silver coins.
Silver solder	Ag = 63, Cu = 30, Zn = 7	For soldering and joining metals
Dental alloy	Ag=33, Hg=52, Sn=12.5, Cu=2.0, Zn=0.5	For filling teeth
Silver palladium	Ag = 40, Pd = 60	Potentiometers and winding of some special instruments.

Alloys of Pb and Sn

Alloy	Percentage Composition	Uses
Solder	Pb = 50, Sn = 50	For soldering.
Pewter	Pb = 20, Sn = 80	In making cups, mugs and other utensils.
Type metal	Pb = 70, Sb = 20 and Sn = 10	For making printing type.
Rose metal	Pb = 22, Sn = 28, Bi = 50	For making electric fuses.
Britannia metal	Sn = 90, Sb = 8, Cu = 2	For making table wares.

Alloys of Copper

Alloy	Percentage Composition	Uses
Brass	Cu = 80, Zn = 20	For making utensils, condenser tubes, wires parts

		of machinery etc.
Bronze or Copper bronze	**Cu = 80, Zn = 10, Sn = 10**	**For making cooking utensils, statues, coins etc.**
Aluminium bronze	**Al = 95, Cu = 5**	**Coins, picture frames, cheap jewellery**
Gun metal	**Cu = 90, Sn = 10**	**For making gun barrels.**
Bell metal	**Cu = 90, Sn = 20**	**For making bells, gongs etc.**
Constantan	**Cu = 60, Ni = 40**	**For electrical apparatus**
German silver	**Cu = 60, Zn = 20, Ni = 20**	**For making silver wire, resistance wires etc.**
Monel metal	**Cu = 30, Ni = 67, Fe and Mn = 3**	**For making acid pumps and acid containers.**
Phosphor bronze	**Cu = 95, Sn = 4.8, P = 0.2**	**For making springs, electrical equipment**
Gold-copper alloy	**Au = 90, Cu = 10**	**For making gold coins, jewellery, watch cases, spectacle rims etc.**

Alloys of Iron

Name	***Percentage***	***Properties***	***Uses***
Stainless steel	**Fe = 73%, Cr = 18%, Ni = 8% and carbon**	**Resists corrosion**	**For making utensils, cutlery and ornamental pieces.**
Magnanese steel	**Fe = 86%, Mn = 13% and carbon**	**Very hard, resistant to wear and tear.**	**For Making rock drills, safes etc.**
Tungsten steel	**Fe = 94%, W = 5% and carbon**	**Retains hardness even at high temperatures**	**For making high speed cutting tools.**
Invar	**Fe = 64%, Ni = 36%**	**Practically no coefficient of expansion.**	**For making watches, meter scales, pendulum rods etc.**
Nickel steel	**Fe = 98–96%, Ni = 2–4%**	**Resistant to corrosion, hard and elastic.**	**For making wire cables, gears, drive shafts etc.**
Permalloy	**Fe = 21%, Ni = 78% and carbon**	**Strongly magnetised by electric current, loses magnetism when current is cut off.**	**For making electromagnets, ocean cables etc.**
Chrome steel	**Fe = 98–96%, Cr = 2–4%**	**High tensile strength**	**For making axles, ball bearings and cutting tools such as files.**
Alnico	**Fe = 60%, Al =12%, Ni = 20%, Co = 8%**	**Highly magnetic**	**For making permanent magnents.**