pyrites. Therefore, **ore of copper is copper pyrites.** Thus, it may be concluded that

All ores are minerals but all minerals are not ores.

TYPES OF ORES

The most common ores of metals are *oxides, sulphides, carbonates, sulphates, halides, etc.* In general, very unreactive metals (such as *gold, silver, platinum etc.*) occur in elemental form or free state.

Some common ores are listed in Table 5.

Table 5. Ores of some metals.

Nature of ore	Metal		Composition
Oxide ores	Aluminium	Bauxite	$Al_2O_3.2H_2O$
	Copper	Cuprite	Cu_2O
	Iron	Magnetite	Fe_3O_4
		Haematite	Fe_2O_3
Sulphide ores	Copper	Copper pyrites	$CuFeS_2$
	Zinc	Copper glance	Cu_2S
	Lead	Zinc blende	ZnS
	Mercury	Galena	PbS
		Cinnabar	HgS

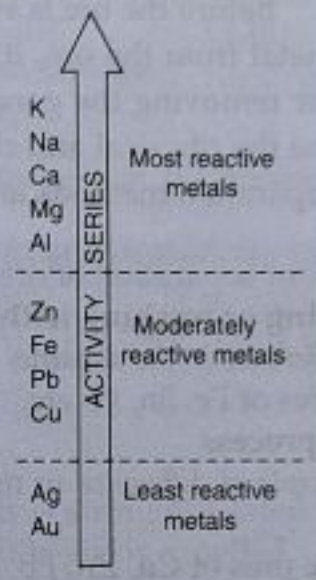
Carbonate ores	Calcium Zinc	Limestone Calamine	$CaCO_3$ $ZnCO_3$
Halide ores	Sodium Magnesium Calcium Silver	Rock salt Carnallite Fluorspar Horn silver	NaCl $KCl\,MgCl_2.6H_2O$ CaF_2 AgCl
Sulphate ores	Calcium Magnesium Barium Lead	Gypsum Epsom salt Barytes Anglesite	$CaSO_4.2H_2O$ $MgSO_4.7H_2O$ $BaSO_4$ $PbSO_4$

- The metals at the bottom of the activity series (silver and gold) are least reactive and therefore, occur in the free state.
- The metals in the middle of the activity series are moderately reactive and they are found mainly as oxides, sulphides or carbonates.
- The metals at the top of the activity series are so reactive that they are never found in nature as free elements. They are found as oxides, carbonates, sulphates, halides etc.

  Copper and silver are also found in the free state as well as in combined states as their sulphide or oxide ores.

  Thus, on the basis of reactivity we can group the metals into the following three categories :

  (*i*) Metals of low reactivity
  (*ii*) Metals of medium reactivity
  (*iii*) Metals of high reactivity



Different techniques are to be used for obtaining the metals falling in each category as discussed ahead :

METALLURGY

The process of extracting pure metals from their ores and then refining them for use is called **metallurgy.**

In other words, the process of metallurgy involves extraction of metals from their ores and then refining them for use. The ores generally contain unwanted impurities such as sand, stone, earthy particles, limestone, mica, etc. These are called **gangue** or **matrix**. The process of metallurgy depends upon the nature of the ore, nature of the metal and the types of impurities present. Therefore, there is not a single method for the extraction of all metals. However, most of the metals can be extracted by a general procedure which involves the following steps :

Various Steps involved in Metallurgical Processes

The following important steps are involved in the extraction of metals from their ores :

1. *Crushing and grinding of the ore.*
2. *Enrichment of the ore or concentration of the ore.*
3. *Extraction of metal from the concentrated ore.*
4. *Refining or purification of the impure metal.*

These steps are briefly discussed below :

1. Crushing and Grinding of the ore

Most of the ores in nature occur as big rocks. They are broken to small pieces with the help of crushers. These pieces are then reduced to fine powder with the help of a ball mill or a stamp mill.

2. Enrichment of the ore or Concentration of the Ore

The ores are usually found mixed up with a large amounts of impurities such as soil, sand, clay and rocky materials etc. known as **gangue**. These unwanted impurities have to be removed before extracting the metals.

The process of removal of unwanted impurities (gangue) from the ore **is called ore enrichment** or **ore concentration.**

Before the ore is subjected to metallurgical processes for the extraction of metal from the ore, it is essential to concentrate the ore. The processes used for removing the gangue from the ore are based on the differences between the the physical and chemical properties of the gangue and the ore. Different separation methods are used, which are discussed in higher classes.

LEARNING PLUS

Different techniques for separation of ore and gangue particles (enrichment of ore):

- **Hydraulic washing or washing with water**
  based upon the difference in the densities of the ore particles and the impurities (gangue).
  ➡ used for oxide ores of Fe, Sn, Pb etc.
- **Froth floatation process**
  based on the principle of difference in the wetting properties of the ore and gangue particles with water and oil.
  ➡ used for sulphide ores of Cu, Zn, Pb, etc.
- **Magnetic separation**
  based on the difference in the magnetic properties of the ores and gangue.
  ➡ used for haematite an ore of Fe.
- **Chemical methods**
  based on the difference in some chemical property of the metal and the impurities.
  ➡ used for bauxite (ore of Al),

The detailed discussion of these methods are beyond the scope of present class.

3. Extraction of the Metal from the Concentrated Ore

The metal is extracted from the concentrated ore by the following steps :

(a) Conversion of the concentrated ore into its oxide. The production of metal from the concentrated ore mainly involves **reduction process.** But it is easier to reduce metal oxides (by reduction) than metal sulphides and carbonates. Therefore, before reduction can be done, the metal sulphides or carbonates must be converted into metal oxides. This can be usually done by two processes known as ***calcination*** and **roasting** process. The method depends upon the nature of the ore. A carbonate ore is converted into oxide by calcination while a sulphide ore is converted into oxide by roasting.

(b) Conversion of oxide to metal by reduction process

These two steps are discussed below :

(a) Conversion of Ore into Metal Oxide

These are briefly discussed below :

Calcination

It is the process of heating the concentrated ore in the absence of air.

The calcination process is used for the following changes :

(*i*) to convert carbonate ores into metal oxide.

(*ii*) to remove water from the hydrated ores.

(*iii*) to remove volatile impurities from the ore.

For example,

(*i*) Zinc occurs as zinc carbonate in calamine ($ZnCO_3$) ore. The ore is calcined i.e., heated strongly in the absence of air to convert it to zinc oxide. During calcination, carbon dioxide is expelled.

$$\underset{\text{Zinc carbonate (Calamine ore)}}{ZnCO_3(s)} \xrightarrow{\text{Calcination}} \underset{\text{Zinc oxide}}{ZnO(s)} + CO_2(g)$$

Similarly, in case of carbonate ore of iron, siderite, $FeCO_3$, calcination converts the carbonate to oxide.

$$\underset{\text{Siderite}}{FeCO_3(s)} \xrightarrow{\text{Calcination}} \underset{\text{Iron (II) oxide}}{FeO(s)} + CO_2(g)$$

Roasting

It is the process of heating the concentrated ore strongly in the presence of excess air.

This process is used for converting sulphide ores to metal oxide. In this process, the following changes take place :

(*i*) the sulphide ores undergo oxidation to their oxides.

(*ii*) moisture is removed

(*iii*) volatile impurities are removed

For example,

(*i*) Zinc occurs as sulphide in zinc blende (ZnS). It is strongly heated in excess of air when it forms zinc oxide and sulphur dioxide gas is expelled.

$$\underset{\text{Zinc sulphide (Zinc blende ore)}}{2ZnS} + \underset{\text{(From air)}}{3O_2} \xrightarrow{\text{Roasting}} \underset{\text{Zinc oxide}}{2ZnO(s)} + 2SO_2(g)$$

(*ii*) Iron occurs as sulphide in iron pyrites ore (FeS_2). During roasting, it gets oxidised to ferric oxide.

$$\underset{\text{Iron pyrites}}{4FeS_2(s)} + 11O_2(g) \xrightarrow{\text{Roasting}} \underset{\text{Ferric oxide}}{2Fe_2O_3(s)} + 8\,SO_2(g)$$

Moreover, any ferrous compound present in the ore is oxidised to ferric.

$$\underset{\text{Ferrous oxide}}{4FeO(s)} + 3O_2(g) \longrightarrow \underset{\text{Ferric oxide}}{2Fe_2O_3(s)}$$

If the ferrous oxide (FeO) is not converted to ferric oxide (Fe_2O_3), it would combine with impurities present and form slag.