Mineral processing

or (Mineral Beneficiation)

1.1 MINERALS

Mineral is a substance having definite chemical composition and internal atomic structure and formed by the inorganic processes of nature Minerals are broadly classified into two types:

1 - Metallic minerals.
2 - Non-metallic minerals.

Metallic minerals are the minerals from which a metal is extracted. A few metallic minerals, their chemical formulae, metal extracted and the percent metal present in the mineral are shown in Table 1.2.
The minerals of Uranium and Thorium are also called **atomic minerals**.

Table 1.2 Metallic minerals.

Mineral	*Chemical formula*	*Metal extracted*	*% metal*
Hematite	Fe_2O_3	Iron	69.94
Magnetite	Fe_3O_4	Iron	72.36
Bauxite	$Al_2O_3{\cdot}2H_2O$	Aluminium	39.11
Braunite	$3Mn_2O_3\ MnSiO_3$	Manganese	63.60
Pyrolusite	MnO_2	Manganese	63.19
Chromite	$FeO\ Cr_2O_3$	Chromium	46.46
Galena	PbS	Lead	86.60
Sphalerite	ZnS	Zinc	67.10
Chalcopyrite	$CuFeS_2$	Copper	34.63
Ilmenite	$FeO\ TiO_2$	Titanium	31.57
Rutile	TiO_2	Titanium	59.95
Zircon	$ZrSiO_4$	Zirconium	49.76
Pitchblende	U_3O_8	Uranium	84.80
Monazite	$(Ce,La,Th)PO_4$	Thorium	–

Non-metallic minerals are the minerals used for industrial purposes for making cement, refractories, glass and ceramics, insulators, fertilizers etc. These minerals are also called **industrial minerals**. Metals are not extracted from these minerals. Some metallic minerals are also used for industrial purposes like Bauxite, Chromite and Zircon for the refractory industry, Pyrolusite for dry battery cells and Ilmenite for the pigment industry, etc. A few non-metallic minerals with their chemical formulae are shown in Table 1.3.

Table 1.3 Non-metallic minerals.

Mineral	*Chemical formula*
Andalusite	Al_2SiO_5
Apatite	$Ca_4(CaF)(PO_4)_3$
Asbestos (Crysotile)	$Mg_3Si_2O_5(OH)_4$
Baryte	$BaSO_4$
Bentonite	$(Ca\ Mg)O\ SiO_2\ (Al\ Fe)_2O_3$
Calcite	$CaCO_3$
Corundum	Al_2O_3
Diamond	C
Diaspore	$Al_2O_3H_2O$
Dolomite	$CaMg(CO_3)_2$
Feldspar	$(Na,K,Ca)\ AlSi_3O_8$
Fluorite	CaF_2
Garnet (Almandine)	$3FeO\ Al_2O_3\ 3SiO_2$
Graphite	C
Gypsum	$CaSO_4.2H_2O$
Kaolinite (China clay)	$H_4Al_2Si_2O_9$
Kyanite	Al_2SiO_5
Limestone	$CaCO_3$
Marble	Chiefly $CaCO_3$
Magnesite	$MgCO_3$
Mica (Muscovite)	$KAl_2(AlSi_3O_{10})(OH,F)_2$
Phosphate rock	$Ca_3(PO_4)_2$
Pyrite	FeS_2
Pyrophyllite	$H\ Al(SiO_3)_2$
Quartz	SiO_2
Sillimanite	$Al_2O_3\ SiO_2$
Talc	$H_2\ Mg_3(SiO_3)_4$
Vermiculite	$3\ MgO(FeAl)_2O_3\ 3SiO_2$

The third type, **coal**, is considered a mineral and is sometimes spoken of as mineral coal in trade, industry and legal affairs. But in a restricted technical sense, coal is not a mineral. It is organic in composition and formed from decaying vegetation and mineral matter. As it is a useful

part of the earth's crust and requires treatment before use, it can be classed as third type of special significance.

Coal line crushing

1.2 IMPORTANT TERMINOLOGY

Minerals do not occur singly in the earth's crust. They occur in association with several other minerals. The following important terminology is used in describing the mineral deposits and related terms.

Rock is an aggregation of several minerals as occurred in the earth's crust.
Ore is also an aggregation of several minerals from which one or more minerals can be exploited /separated at profit.
All Ores are Rocks, but all Rocks are not Ores
An Ore at one place may be a Rock at other place

Ore Minerals or **Valuable Minerals** are those minerals which contain an economically exploitable quantity of some metal or non-metal.

Gangue Minerals are usually the non-metallic minerals associated with ore minerals which are worthless as a source for that metal or otherwise. These are usually unwanted, waste or useless minerals. These gangue minerals occasionally find use as source of by-products. For example, pyrite present in Lead and Zinc ores is a gangue mineral but it is

separated as by-product for extraction of sulphur after the lead and zinc minerals are separated.

Ore Deposits are the natural deposits of ore minerals.

Ore is an aggregation of valuable and gangue minerals.

Simple Ore is one from which a single metal can be extracted. For example, only Iron is extracted from Hematite ore, Aluminium is extracted from Bauxite ore, Chromium is extracted from Chromite ore, etc.
Complex Ore is one from which two or more metals can be extracted. Lead, Zinc and Copper metals are extracted from Lead-Zinc-Copper Ore.

Metal Content of a mineral is generally expressed in percent of metal present in the mineral. It is calculated by taking the atomic weights of the elements present in the mineral.

Iron ore

Let us consider **Hematite (Fe2O3)**
Atomic weight of Iron = 55.85
Atomic weight of Oxygen = 16.00
Molecular weight of Hematite = 55.85 × 2 + 16 × 3 = 159.7

$$\text{Percent Iron} = \frac{55.85 \times 2}{159.7} \times 100 = 69.94$$

Assay Value or **Tenor** is the percent metal, percent valuable mineral, or ounces precious metal per ton depending upon the type of ore involved.

Grade is a relative term used to represent the value of an ore.

High Grade Ore is an ore having a high assay value and **Low Grade Ore** is an ore having a low assay value. The Ore having an assay value between that of high and low value is called **Medium Grade Ore.**

Rich Ore and **Lean Ore** are the other terms of common usage where an ore with a high assay value is rich ore and an ore with low assay value is lean ore.

1.3 BENEFICIATION

Separation of the wanted part from the aggregation of wanted and unwanted parts by physical methods is termed as Beneficiation. Separation of rice from the mixture of rice and stones is the example known to everyone.

1.4 MINERAL BENEFICIATION

As defined by A.M. Gaudin Mineral Beneficiation can be defined as processing of raw minerals to yield marketable products and waste by means of physical or mechanical methods in such a way that the physical and chemical identity of the minerals are not destroyed [2].
It follows that mineral beneficiation is a process designed to meet the needs of the constumer of minerals.

Run-of-mine Ore is an ore directly taken from the mine, as it is mined.
Figure 1.1 shows the successive major steps involved in processing the ores.
Geologists conduct a geological survey and estimate the ore reserves, their quality and tenor. Mining engineers mine the ore and bring it to the surface of the earth. Mineral Engineers beneficiate the ore to higher tenor. Thus beneficiated ore, if it is metallic ore, is smelted and the metal is extracted which is further utilized for the production of alloys. If the ore is non metallic, beneficiated ore is directly utilized for the production of various products like cement, fertilizers etc.

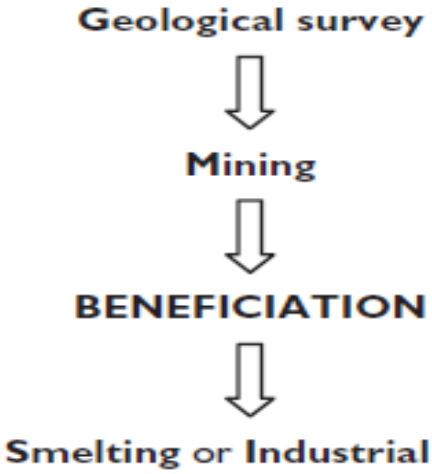
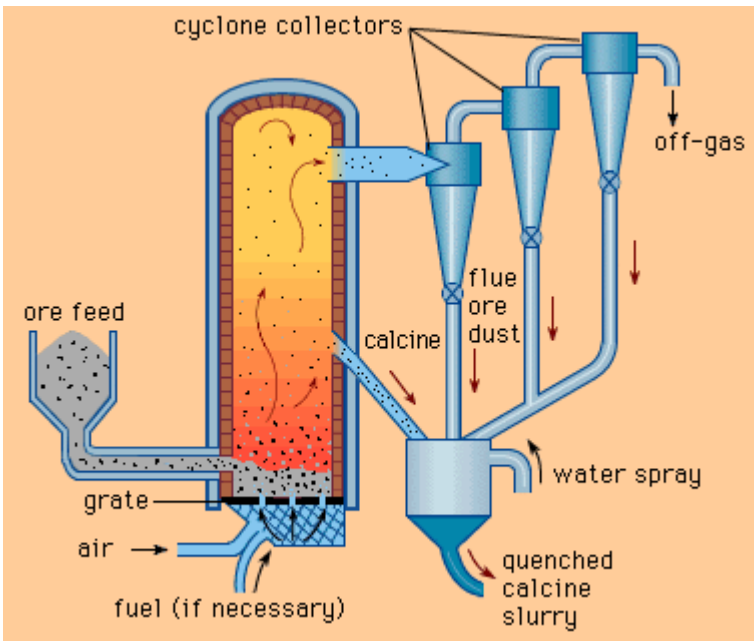


Figure 1.1 The major steps in processing of ores.

Smelting operation, for the extraction of a metal, requires:

- Uniform quality of the ore.
- Appropriate size of the ore.
- Minimum tenor of the ore.



Smelting processes

Beneficiation of run-of-mine ore is done to achieve the above. The primary object of Mineral Beneficiation is to eliminate either unwanted chemical species or particles of unsuitable size or structure.
During beneficiation, much of the gangue minerals, usually present in large quantities in many ores, are eliminated or removed.

The benefits are:
1- Freight and handling costs reduced.
2- Cost of extraction (smelting) reduced.
3- Loss of metal in slag reduced.

By doing beneficiation, lean ores can be made technically suitable for extraction of metal. Mineral Beneficiation is usually carried out at the mine site. The essential reason is to reduce the bulk of the ore which must be transported, thus saving the transport cost.