



CHAPTER

Properties of Minerals for Processing

2.1 SAMPLING

Sampling is a process of obtaining a small portion from a large quantity of a similar material such that, it truly represents the composition of the whole lot. It is an important step before testing of any material in the laboratory.

Sampling of homogeneous materials is easy as compared to heterogeneous materials and hence, has to be conducted carefully. It is so because unlike heterogeneous materials, homogeneous materials have a uniform composition. However, almost all metallurgical materials are heterogeneous in nature.

2.1.1 Sampling of Ores/Minerals

The process of sampling is complicated because of the following reasons:

- (1) A large variety of constituents are present in ores and minerals.
- (2) There is a large variation in the distribution of these constituents throughout the material.
- (3) In many cases, weight of the sample may vary from, 0.5 to 5 gm or 10 gm. Small fraction from large quantity like 50 to 250 tonnes are not true representative of the entire lot.

The size of the sample required for testing depends on the method of testing and the testing machine which is used. However, sampling may involve three operations, namely, **crushing** and/or **grinding**, **mixing** and finally **cutting**. These operations may be executed repeatedly wherein the quantity of sample can be reduced to a desired weight.

Sampling should be based on the relation between maximum particle size and the amount of sample. The size of ore/mineral particles taken for sampling depends on uniformity of composition, i.e., if the composition is more uniform, smaller particle size of the sample is taken and vice versa. The safer way is that the weight of the sample taken should be directly proportional to the square of the diameter of the largest particle.

2.1.4 Machine Cutting Method

It can be carried out in a continuous or in an intermittent manner. This method is quite fast, cheap and gives more accurate results.

Ores Containing Metallics

When ores containing native gold (Ag), silver (Au), copper (Cu) as well as other malleable minerals are crushed, the metallics are left on the sieve as flat scales or spherical particles. When such ores are sampled, in order to extract metallics, care should be taken. In such cases, initially the original sample must be carefully weighed followed by a separate preservation of particles found on each sieve. Lastly, these particles are weighed.

2.2 PHYSICAL AND CHEMICAL CHARACTERISTICS OF MINERALS

The physical and chemical characteristics of minerals and rocks are considered in mineral processing to achieve the separation. Based on the fact that both the valuable and waste minerals exhibit different behavioural patterns, appropriate separation techniques are employed.

Some of the important properties used for mineral processing are as follows:

Physical Properties

- | | |
|---|---------------------------------------|
| (1) Colour and lustre | (6) Mineral aggregation |
| (2) Hardness or softness | (7) Specific gravity |
| (3) Brittleness or friability | (8) Electro-conductivity |
| (4) Crystal structure, crystal habit and fracture | (9) Magnetic susceptibility |
| (5) Cleavage, parting, fracture, and tenacity
friction | (10) Change in porosity on
heating |
| | (11) Decrepitation |

Chemical Properties

Due to the mechanical nature of ore processing operations, chemical properties utilization are limited. The chemical properties useful in mineral processing are those which may affect the physical behaviour of minerals during their processing.

Important chemical properties are as follows:

- (1) Change in magnetic properties by heat
- (2) Surface properties include greasiness, adhesion, wettability, contact angle, polarity and surface tension.
- (3) Other properties include reactions with acids and radioactivity.

2.2.1 Colour and Lustre

Colour is the most obvious property of a mineral, but it is often non-diagnostic. It is caused by an electromagnetic radiation interacting with electrons (except in the case of incandescence, which does not apply to minerals). Examples of such minerals are *malachite* (green) and *azurite* (blue).

Lustre indicates how light reflects from the mineral's surface with regards to its quality and intensity. There are numerous qualitative terms used to describe this property, which are split into metallic and non-metallic categories. Metallic and sub-metallic minerals have high reflectivity like metal. Non-metallic lustre include, such as in diamond; vitreous, which is a glassy lustre. Figure 2.3 indicates the metallic lustre in pyrite.



Figure 2.3 Metallic lustre in pyrite

These properties are most important in the case of technique involving separation by simply hand-picking. Slight differences in colour or in lustre provide valuable aids in hand-picking. The colour of the mineral is different to its lustre since the former refers to the actual colour of the mineral, whereas the latter refers to the appearance of the mineral in ordinary reflected light. Some of the minerals with their colour and lustre are listed below.

Mineral	Colour
Chalcopyrite (CuFeS_2)	Brass yellow
Pyrite (FeS_2)	Pale yellow
Arsenopyrite (FeAsS)	White
Mineral	Lustre
Quartz	Vitreous
Sphalerite	Resinous
Diamond	Adamantine
Chalk	Dull
Talc	Pearly

Thus, the separating force used is the way of visual which can be either manual or automated. Figure 2.4 indicates the different colours of garnets group like green uvarovite (left) and red-pink grossular (right).

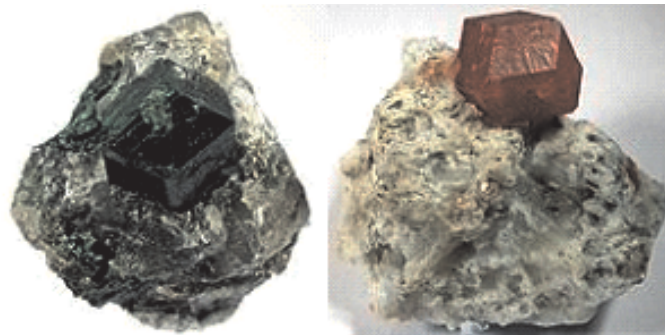


Figure 2.4 Colour of garnet group

2.2.2 Hardness or Softness

The hardness of a mineral defines how much it can resist scratching. It means ability to scratch one another being considered the measure of hardness. This physical property is controlled by the chemical composition and crystalline structure of a mineral. A mineral's hardness is not necessarily constant for all sides in terms of its crystal structure. Crystallographic weakness renders some sides than others. An example of this property exists in kyanite, which has a Mohs hardness of $5\frac{1}{2}$ parallel to $[0\ 0\ 1]$, but 7 parallel to $[1\ 0\ 0]$. The most common scale of measurement is the Mohs hardness scale. Defined by the ten indicators (numbers or positions), a mineral with a higher index scratches all those having lower index. It means each mineral in the list can scratch all those listed above it. The scale ranges from talc to diamond which is the hardest natural material. The scale is mentioned as follows:

Mohs hardness	Mineral	Chemical formula
1	Talc	$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
2	Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
3	Calcite	CaCO_3
4	Fluorite	CaF_2
5	Apatite	$\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})$ Primary group
6	Orthoclase	KAlSi_3O_8
7	Quartz	SiO_2
8	Topaz	$\text{Al}_2\text{SiO}_4(\text{OH}, \text{F})_2$
9	Corundum	Al_2O_3
10	Diamond	C

Hardness affects the wear of crushing machines, i.e., the harder the mineral, the greater the wear of the crushing surfaces.

2.2.3 Brittleness or Friability

Some minerals are excessively hard and at the same time some are excessively soft. Some are difficult to break, e.g., horn silver, native copper, mica, talc, gypsum, feldspar, etc. Some minerals are brittle and hence, break them very easily, e.g., some varieties of quartz. With an agitation a hard brittle mineral makes more fines or slime than one which is soft and tough.

2.2.4 Crystal Structure, Crystal Habit and Fracture

Crystal Structure

Crystal structure results from the orderly geometric arrangement of atoms in the internal structure of a mineral. This crystal structure is based on regular internal atomic or ionic arrangement that is often expressed in the geometric form that the crystal takes. Crystal structure is always periodic and can be determined by X-ray diffraction. Minerals are typically described by their symmetry content and are classified into seven crystal families.

These families can be described by the relative lengths of the three crystallographic axes, and the angles between them; these relationships correspond to the symmetry operations. They are summarized as follows; a , b , and c represent the axes, and α , β , γ represent the angle opposite the respective crystallographic axis (e.g., α is the angle opposite the a -axis, viz., and the angle between the b and c axes):

Crystal family	Lengths	Angles	Common examples
Isometric	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Garnet, halite, pyrite
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Rutile, zircon, and alusite
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Olivine, aragonite, orthopyroxenes
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	Quartz, calcite, tourmaline
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$	Clinopyroxenes, orthoclase, gypsum
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	Anorthite, albite, kyanite

The hexagonal crystal family is also split into two crystal systems the trigonal, which has a threefold axis of symmetry, and the hexagonal, which has a sixfold axis of symmetry.

Chemistry and crystal structure together define a mineral. Differences in crystal structure and chemistry greatly influence other physical properties of the mineral. The carbon allotropes, namely, diamond and graphite have vastly different properties; diamond is the hardest natural substance and has an adamantine lustre, and belongs to the isometric crystal family, whereas graphite is very soft and has a greasy lustre, and crystallises in the hexagonal family. This difference is accounted by the differences in bonding. In diamond, the carbons are in sp^3 hybrid orbitals, which mean they form a framework where each carbon is covalently bonded to three neighbours in a tetrahedral fashion; on the other hand, graphite is composed of sheets of carbons in sp^2 hybrid orbitals, where each carbon is bonded covalently to only two others. These sheets are held together by much weaker van der Waals forces, and this discrepancy translates to big macroscopic differences.

Crystal Habit

Crystal habit refers to the overall shape of a crystal. Several terms are used to describe this property. Common habits include acicular, which describes needle-like crystals as in natrolite, bladed, dendritic (tree-pattern, common in native copper), equant, which is typical of garnet, prismatic (elongated in one direction), and tabular, which differs from bladed habit where in the former is platy, whereas the latter has a defined elongation. Related to crystal form, the quality of crystal faces is diagnostic of some minerals, especially with a petrographic microscope.

Fracture

The shape acquired by a mineral is often determined by the presence or absence of a crystalline structure. For example, galena tends to break into cubes, feldspar tends to break into elongated fragments, mica tends to break into flat scales, and magnetite tends to break into rounded grains. All these shapes directly affect, the ability of the grain to settle in water or the ability of the grain to move upon a plane surface.

2.2.5 Cleavage, Parting, Friction and Tenacity

Cleavage

By definition, minerals have a characteristic atomic arrangement. Weakness in this crystalline structure causes planes of weakness, and the breakage of a mineral along such planes is termed **cleavage**. The quality of cleavage can be described based on how cleanly and easily the mineral breaks; common descriptors, in order of decreasing quality, are ‘perfect’, ‘good’, ‘distinct’, and ‘poor’.’ In particularly transparent mineral, or in thin-section, cleavage can be seen as a series of parallel lines marking the planar surfaces when viewed at a side. Cleavage is not a universal property among minerals; for example, quartz, consisting of extensively interconnected silica tetrahedra, does not have a crystallographic weakness which would allow it to cleave. In contrast, mica, which has perfect basal cleavage, consists of sheets of silica tetrahedra which are very weakly held together. Minerals with many cleavages might not break equally well in all of the directions; for example, calcite has good cleavage in three direction, but gypsum has perfect cleavage in one direction, and poor cleavage in two other directions. Angles between cleavage planes vary between minerals. For example, as the amphiboles are double-chain silicates and the pyroxenes are single-chain silicates, the angle between their cleavage planes is different. The pyroxenes cleave in two directions at approximately 90° whereas the amphiboles distinctively cleave in two directions separated by approximately 120° and 60° . The cleavage angles can be measured with a contact goniometer, which is similar to a protractor.

Parting

Parting, sometimes called **false cleavage**, is similar in appearance to cleavage, but it is produced by structural defects in the mineral as opposed to systematic weakness. Parting varies from crystal to crystal of a mineral, whereas all crystals of a given mineral will cleave if the atomic structure allows for that property. In general, parting is created by some stress applied to a crystal. The sources of the stresses include deformation (e.g., an increase in pressure), or twinning. Minerals that often display parting include the haematite (Fe_2O_3), magnetite (Fe_3O_4), and corundum (Al_2O_3).

The behaviour of particles is governed by the laws of settling as follows:

Two particles of same size and shape, but different specific gravity	→	the heavier will settle faster than the lighter
Two particles of same specific gravity and shape, but different in size	→	the larger (large size) will settle faster than the smaller
Particles differing in shape also behave differently	→	a rounded grain settling faster than a tabular grain

In separation using heavy solution (i.e., heavy media separation) the particles of lower specific gravity float and those of higher specific gravity sink, irrespective of particle size and shape. It is used for coal cleaning purpose.

2.2.8 Electro-Conductivity

To utilize the phenomenon of electro-conductivity particles are passed through high voltage zone. Some minerals are relatively good conductors while others are relatively poor conductors of electricity. By applying this principle, it is possible to affect a commercial separation of two or more minerals.

It is found that most of the sulphide minerals and the metals themselves are conductors of electricity in varying degrees and the gangue minerals, in general, are poor conductors. Therefore, if neutral ore particles are brought into contact with an electrode carrying a static charge, the better conductors become similarly charged and are repelled, whereas poor conductors do not.

2.2.9 Magnetic Susceptibility

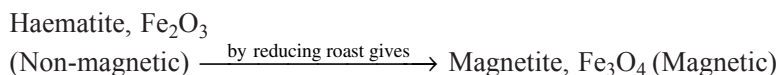
Magnetism of minerals and metals vary widely as follows:

- (i) Some minerals and metals have strong magnetism (i.e., strong attraction to magnet), e.g., magnetite (Fe_3O_4), some forms of pyrrhotite (FeS), cast iron, wrought iron, steel, nickel (Ni), cobalt (Co), etc. The minerals which are strongly attracted by a magnet are called ferromagnetic.
- (ii) Other minerals have very weak magnetism, e.g., franklinite, chromite (FeCr_2O_4), serpentine, iron-bearing sphalerite, (ZnS). The minerals which are weakly attracted are paramagnetic.
- (iii) Some other show no magnetism at all, e.g., quartz, calcite, gypsum, feldspar, etc.

By using properly constructed magnets, it is possible to separate magnetic minerals from non-magnetic or, more magnetic minerals from less magnetic minerals. Such a separation process is called magnetic separation. The application of this process is limited due to the relatively high initial cost of the machinery, if the minerals are not highly magnetic.

Change in Magnetic Properties by Heat

Certain minerals (mainly that of iron) when heated lose oxygen, carbonic acid or sulphur, and are changed from being non-magnetic or only slightly magnetic to strong magnetic. Then these minerals can be separated from other non-magnetic minerals. For example,



2.2.10 Change of Porosity by Heat

Certain minerals, when heated, lose a part of their volatile constituents and become porous or spongy. Air fills these pores and gives the mineral a lower apparent specific gravity, which sometimes aids separation.

2.2.11 Decrepitation

Some minerals, when kept on a hot plate, decrepitate (or fly to pieces) due to the unequal expansion which overcomes the cohesion of the molecules. For example, calcite, fluorite, barite, etc. By decrepitating and sieve analysis, a mineral which decrepitates can be separated from one which does not decrepitate. Thus, the latter kind of mineral can be found on the sieve, while that which had finely decrepitated will pass through the sieve.

2.2.12 Surface Properties

The surface properties of a mineral determine its behaviour at an interface or surface between two phases. A separation of minerals can be achieved if one mineral or group of minerals adheres to a surface of some kind presented equally to all the minerals. For example, in flotation, air bubbles attach themselves to some minerals and not to others.

Gold adheres to an amalgamated plate surface, whereas quartz and other common minerals do not.

Diamonds adhere to a greasy surface, while quartz does not, effecting their economical separation. In flotation, surface properties of minerals are varied by the addition of chemical reagents, and by this means, the valuable minerals are given the ability to adhere to the air-water surfaces of air bubbles. A selective adhesion of oil for certain minerals has also been used in certain older flotation processes.

2.2.13 Other Properties

Other properties can be used to diagnose minerals. These are less general, and apply to specific minerals. For example, dropping dilute acid (often 10 per cent HCl) aids in distinguishing carbonates from other mineral classes. The acid

reacts with the carbonate ($[\text{CO}_3]^{2-}$) group, which causes the affected area to effervesce (bubbles or froth) giving off carbon dioxide gas. Zeolite minerals will not effervesce in acid; instead, they become frosted after 5–10 minutes, and if left in acid for a day, they dissolve.

Minerals can also be tested for taste or smell, e.g., sylvite, has a pronounced bitter taste. Sulphides have a characteristic smell, especially as its samples are fractured, reacting, or powdered.

Radioactivity is a rare property; minerals may be composed of radioactive elements, such as presence of uranium (U) in uraninite, autunite, and carnotite. The radioactive element damages the mineral crystal. It can be measured by thin-section petrography method.

Overall, although the mentioned properties help in the separation of valuable minerals from the valueless minerals (gangue), this type of separation is rarely achieved in one step, i.e., numbers of steps are required. Hence, machines are mainly used for complete separation.

For uniform results and most economical operation, continuity of operation in all stages of treatment is most desirable. Hence, mineral processing machines are designed primarily to work on a continuous flow of material. Batch methods are confined mainly for laboratory testing or to special small-scale work.

2.3 CHARACTERISTICS OF INDUSTRIAL MINERALS

2.3.1 Haematite (Fe_2O_3)

Haematite is one of the most abundant minerals on the earth's surface and in the shallow crust. It is an iron oxide with a chemical composition of Fe_2O_3 . It is a common rock-forming mineral found in almost all the parts of the world. Haematite is the most important ore of iron. Haematite has a wide variety of other uses, but their economic significance is very small as compared to the importance as iron ore. The haematite mineral is used to produce pigments, preparations for heavy media separation, radiation shielding, ballast, and many other products.

Haematite has an extremely variable appearance. Its lustre can range from earthy to submetallic or metallic. Its colour ranges from red to brown and black to grey to silver. Even though haematite has a highly variable appearance, it always produces a reddish streak. The reddish streak is the most important clue for identifying haematite. Haematite is not magnetic and will not respond to a common magnet. However, many specimens of haematite contain enough magnetite and hence, are attracted to a magnet. This can lead to an incorrect assumption that the specimen is magnetite or the weakly magnetic pyrrhotite. The investigator must check other properties to make a proper identification. If the investigator checks the streak, a reddish streak will rule out identification as magnetite or pyrrhotite. Instead, if the specimen is magnetic and has a reddish streak, it is most likely a combination of haematite and magnetite. Mineralogical properties of haematite mineral are given below.

Cleavage	: Indistinct, parting on {111}, very good
Mohs hardness	: 5.5 to 6.5
Specific gravity	: 5.17–5.18
Diagnostic properties	: Lodestone, or loadstone, (magnetic with definite north and south poles)
Chemical composition	: Fe_3O_4
Crystal system	: Isometric hexoctahedral
Uses	: The most important ore of Fe, pigment, heavy media separation, radiation shielding, ballast, polishing compounds, a minor gemstone.

2.3.3 Galena (PbS)

Galena is a lead sulphide mineral with a chemical composition of PbS. It is the world's primary ore of lead and is mined from a large number of deposits in many countries. Galena is easy to identify. Freshly broken pieces exhibit perfect cleavage in three directions that intersect at 90°. It has a distinct silver colour and a bright metallic lustre. Galena tarnishes to a dull grey. Since lead is a primary element in galena, and the mineral has a high specific gravity (7.4 to 7.6) which is immediately noticed when picking up even small pieces. Galena is soft and produces a grey to black streak. Crystals are common and they usually are cubes, octahedrons, etc. Most of the lead minerals, such as cerussite and anglesite are secondary minerals formed from galena. Impurities in the structure of galena, such as silver and bismuth, can change galena's cleavage properties. Galena containing bismuth may exhibit octahedral cleavage, and silver in galena may cause a specimen to exhibit flaky, slightly bent cleavage fragments. Mineralogical properties of galena are given below.

Chemical classification	: Sulphide
Colour	: Fresh surfaces are bright silver in colour with a bright metallic lustre, tarnishes to a dull lead grey
Streak	: Lead grey to black
Lustre	: Metallic on fresh surfaces, tarnishes dull
Diaphaneity	: Opaque
Cleavage	: Perfect, cubic, three directions at right angles
Mohs hardness	: 2.5+
Specific gravity	: 7.4 to 7.6

Cleavage	: Perfect, cubic, three directions at right angles
Mohs hardness	: 3.5–copper penny
Specific gravity	: 4.1–4.3, average = 4.19
Diagnostic properties	: Colour, lustre,
Chemical composition	: FeS_2 (CuFeS_2)
Crystal system	: Tetragonal
Uses	: An ore of Cu

2.3.5 Azurite $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$

Azurite is a soft and deep blue copper mineral produced by weathering of copper ore deposits. It is also known as chessylite after the type locality at Chessy-les-Mines near Lyon, France. A secondary copper mineral frequently found in the oxidised zones of copper bearing ore deposits. Azurite is typically found as tabular to prismatic crystals of a deep ‘azure blue’ colour with splendid vitreous faces. Azurite is often pseudomorphed to Malachite, and the two are frequently found together. Following table indicates mineralogical properties of azurite are given below.

Chemical classification	: Carbonate mineral
Colour	: Azure blue, blue, light
Streak	: Light blue
Lustre	: Vitreous
Diaphaneity	: Opaque
Cleavage	: Perfect Perfect on (011); on (100) fair; on (110) in traces.
Mohs hardness	: 3.5-4.0
Specific gravity	: $3.77\text{--}3.83\text{g/cm}^3$
Diagnostic properties	: Colour, lustre,
Chemical composition	: $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$
Crystal system	: Monoclinic
Uses	: An ore of Cu

2.3.6 Monazite $(\text{RE Th})_3(\text{PO}_4)_4$

Monazite is a reddish-brown phosphate mineral containing rare earth metals. It occurs usually in small isolated crystals. There are at least four different kinds of monazite, depending on relative elemental composition of the mineral which are as follows. In above formula RE means rare earth elements.

1. Monazite-(Ce), (Ce, La, Nd, Th)PO₄ (the most common member)
2. Monazite-(La), (La, Ce, Nd)PO₄
3. Monazite-(Nd), (Nd, La, Ce)PO₄
4. Monazite-(Sm), (Sm, Gd, Ce, Th)PO₄

Monazite is an important ore for thorium (Th), lanthanum (La), and cerium (Ce). It is often found in placer deposits. India, Madagascar, and South Africa have large deposits of monazite sands. The deposits in India are particularly rich in monazite. It is relatively dense, about 4.6 to 5.7 g/cm³. Lanthanum is the most common rare earth element in monazite-(La), and so forth. Silica, SiO₂, will be present in trace amounts, as well as small amounts of uranium (U) and thorium. Due to the alpha decay of thorium and uranium, monazite contains a significant amount of helium (He), which can be extracted by heating. Due to the presence of thorium and less commonly uranium within monazite, it can be radioactive. Due to its radioactive nature, the monazite within rocks is a useful tool for radiometric dating geological events, such as crystallisation, heating or deformation of the rock. Some mineralogical properties of monazite (RE Th)₃(PO₄)₄ are given below.

Chemical classification	: Phosphate minerals (Ce, La)PO ₄
Colour	: Reddish brown, brown, pale yellow, pink, green, grey
Streak	: White
Lustre	: Resinous, vitreous to adamantine
Diaphaneity	: Translucent to opaque
Cleavage	: Distinct on [100], poor on [010].
Mohs hardness	: 5.0 to 5.5
Specific gravity	: 4.6–5.7 (4.98–5.43 for monazite—Ce)
Diagnostic properties	: Radioactive if thorium rich, paramagnetic dull brown cathodoluminescence
Chemical composition	: Typically, the lanthanides in such monazites contain about 45-48 per cent Ce, about 24 per cent La, about 17 per cent neodymium (Nd), about 5 per cent praseodymium (Pr), and minor quantities of samarium (Sm), gadolinium (Gd), and yttrium (Y). Europium concentrations tend to be low, about 0.05 per cent.
Crystal system	: Monoclinic
Uses	: For the use of extraction of rare earth metals, such as Ce, La, Th, Nd, etc.

Approximately 70-80 per cent of the world's dry bauxite production is processed first into alumina, and then into aluminium. Bauxite rocks are typically classified according to their intended commercial applications: metallurgical, abrasive, cement, chemical, and refractory. Following are the mineralogical properties of bauxite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$).

Chemical classification	: Aluminium hydroxide, but the compound may contain other substances, including Fe oxide and silica.
Colour	: White, grey, sometimes stained yellow, orange red, pink, brown or yellow due to Fe or included Fe minerals.
Streak	: Usually white but Fe stain can fade
Lustre	: Dull, earthy
Diaphaneity	: Opaque
Cleavage	: None
Mohs hardness	: 1-3
Specific gravity	: 2-2.5
Diagnostic properties	: Often exhibits pisolitic structure, colour
Chemical composition	: Variable but always rich in aluminum oxides and aluminium hydroxides.
Crystal system	: N/a
Uses	: Primary ore of aluminium, also used as an abrasive

2.3.10 Ilmenite (FeTiO_3)

Ilmenite is the titanium-iron oxide mineral with the idealised formula of FeTiO_3 . It is a weakly magnetic black or steel-grey solid. From the commercial perspective, ilmenite is the most important ore of titanium (Ti). Ilmenite most often contains appreciable quantities of magnesium and manganese, and the full chemical formula can be expressed as $(\text{Fe}, \text{Mg}, \text{Mn}, \text{TiO}_3)$. Ilmenite forms a solid solution with geikielite (MgTiO) and pyrophanite (MnTiO_3) which are magnesian and manganiferous end-members of the solid solution series.

Most ilmenite is mined for titanium dioxide (TiO_2) production. Finely grounded titanium dioxide is a bright white powder widely used as a base pigment in paint, paper and plastics. North America and Europe together consume about 50 per cent of the world's titanium dioxide production. Demand by India and China is growing rapidly and may eventually surpass Western consumption. Global TiO_2 pigment demands for 2010 was 5.3 Mt with annual growth expected to be about 3-4 per cent.

Carbon (anthracite) and energy are added in large electric arc smelting furnaces to convert the ilmenite into molten iron bath and slag rich in titanium dioxide. The iron can be further processed as pig iron and then as continuous

is preferred and largely followed which involves low cost and less labour. Since then bulk mining is followed by mineral dressing/processing.

The merits of processing the mineral before extraction (by smelting) are as follows:

- (1) **Saving in freight:** Since no freight has to be paid during transport on the waste discarded by the dressing operations.
- (2) **Reduced losses of metal at the smelter:** This is because of reduction in the amount of metal-bearing slag produced at the smelter.
- (3) **Reduction in total smelting cost:** This is due to reduction in the amount of mineral to be smelted.

Against these above listed merits, there are major demerits like:

- (1) The material losses of valuable minerals incurred in dressing the ore.
- (2) The total cost of the dressing operation.

In spite of these demerits, particularly for low-grade ores of non-ferrous and rare metals, mineral processing/dressing are always carried out before metal extraction so as to reduce the overall cost associated with the metal extraction from its ore.

The engineers and geologists have to search for new sites to discover, rather new ore deposits on a huge scale, to meet the ever increasing demand for various metals and materials. Chemical methods like various types of roasting, special leaching techniques and ion exchange have to be developed and used for mineral processing of some of the ores which are difficult to concentrate by physical methods available. Also, the recent developments in mineral processing should aim at the large capacity and higher efficiency of the processes. Needless to say that minerals should be consumed judiciously, since they are natural resources which are non-renewable.

● Questions ●

1. What is a sampling? How it is done for ores/minerals?
2. What are the important properties of minerals? Discuss briefly.
3. Which properties play an important role in gravity separation processes?
4. How does specific gravity play a vital role in gravity concentration processes?
5. Explain the importance of physical properties of minerals.
6. Explain the importance of chemical properties of minerals.
7. What is electro-conductivity? How it can be helpful for separation of minerals?
8. Discuss, in brief, the characteristics of haematite and magnetite minerals.
9. Which are the principal common non-ferrous minerals? Discuss.
10. What are the merits of processing the mineral before metal extraction?