Mineral Processing

India's major mineral resources include Coal, Iron , Diamonds, Limestone and Thorium. A national level agency National Natural Resources Management System (NNRMS) was established in 1983 for integrated natural resources management in the country. It is supported by Planning Commission (India) and Department of Space. Metallic minerals are the minerals which contain one or more metallic elements. They occur in rare, naturally formed concentrations known as mineral deposits. Metallic minerals available from India are gold, zinc, iron ore, manganese ore, bauxite, silver, lead, tin, copper and chromites.

Copper is mainly used in industrial applications, electrical/electronic equipment and Consumer products such as utensils. Major resources of copper are available at Rajasthan, Madhya Pradesh and Jharkhand.

Manganese is used in the manufacture of steel, paint, glass, bleaching powder, dry cell, batteries and also present in certain enzymes of the human body. It is used to for a number of alloys. It is found in Karnataka, Madhya Pradesh, and Maharashtra.

Zinc is a bluish-white, lustrous, diamagnetic metal. It is also a fair conductor of electricity.It is found in Andhra Pradesh, Madhya Pradesh, Bihar and Maharashtra states.

India is the world's third biggest exporter of iron ore as of 2013. In the last renewal in 2018, a total of 5.5 million tonne per annum (MTPA) of high-grade iron ore export was allowed to Japan andkorea.Themajoramountof hematite isfoundin Orissa, Jharkhand, Chhattisgarh, Karnataka and Goa. It is also used in coal washeries, cement and glass industries. Public sector companies like National Mineral Development Corporation and Steel Authority of India.

Chromite is an oxide of chromium and iron. It is the only commercial source of chromium. It is found in odisha, Manipur.Nagaland and Jharkhand.

Difference between Mineral and Ore

Most of the minerals are unstable to exist in natural form in the earth's crust, so they become stable by combining with some other elements, and this combination is known as ores. Ores are the minerals from which metal can be extracted easily.

The major differences between the mineral and ore:-

MINERAL	ORE
Minerals are the natural occurring inorganic substances that exist in earth's crust.	Ores are the Minerals from which metal can be extracted economically and conveniently.
They have definite crystalline structure	They do not have definite crystalline structure
All minerals are not ores.	All ores are not minerals.
Example: Magnetite and Cryolite are the mineral of Aluminium and Iron.	Example: Bauxite and Hematite are the ores of Aluminium and Iron.
Minerals may or may not contain a good percentage of metals.	Ore always contains a good percentage of metal.

Mineral: It is the natural occurring inorganic substance which contains metals and non-metals from which metals may or may not be extracted economically; Examples of minerals are Hematite, Magnetite, Bauxtite, Cryolite, etc.

Ore:- It is the mineral from which metal can be extracted economically. Examples of ore are Hematite, Bauxite, etc.

Scope of Ore dressing

The scope of mineral dressing are:-

1. It helps in eliminating unwanted chemical species from the bulk of the ore.

2. It helps in eliminating particles improper size and physical structure which may adversely affect the working of smelters, roasters etc. This implies production of ore particles of specific size range with proper physical properties is of great importance.

The objectives of Mineral Dressing are:-

1. To eliminate unwanted chemical species: To prepare the ore particle from chemical stand point, primarily involving the following steps: a. Liberation of dissimilar particles from each other appearing in the bulk ore. b. Separation of chemically dissimilar particles.
2. To prepare ore from physical standpoint. This involves: a. Reduction in size. b. Separation of particles of dissimilar physical nature. So the first step in ore beneficiation is size reduction causing libation. This is followed by separation of liberated particles as the second step in the process.

Communition

The process of comminution is the crushing and grinding of a material / ore to reduce it **to** smaller or finer particles. Comminution is a critical component of many mineral processing flow sheets. When separating the precious metals from waste rock, before it goes onto further mineral processing. There are several methods of comminution. Comminution of solid materials requires different types of crushers and mills depending on the feed properties such as hardness at various size ranges and application requirements such as throughput and maintenance. The most common machines for the comminution of coarse feed material (primary crushers) are the jaw crusher, crusher and crusher, the ball mill, vertical roller mill, hammer mill, roller press or high compression roller mill, vibration mill.

Liberation

Liberation is the creation of individual particles that are more homogeneous in their composition. Liberation is achieved by size reduction of the ROM coal.

Physical and chemical property 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 (2) Mineral aggregation (3) Hardness or softness (4) Specific gravity (5) Brittleness or friability (6) Electro-conductivity (7) Crystal structure, crystal habit and fracture (8) Magnetic susceptibility.

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. 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.

Minerals	Colour
Chalcopyrite ($CuFeS_2$)	Brass yellow
Pyrite (FeS_2)	Pale yellow
Arsenopyrite (FeAsS)	White

Minerals	Lustre
Quartz	Vitreous
Sphalerite	Resinous
Talc	Pearly

Thus, the separating force used is the way of visual which can be either manual or automated.

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 5½ 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.

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

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.

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 week 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.

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.

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, Haematite, Fe2O3 (Non-magnetic) can be changed to magnetic by roasting .Fe_3O_4

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.

Crushing

Some ores occur in nature as mixtures of discrete mineral particles, such as gold in gravel beds and streams and diamonds in mines. These mixtures require little or no crushing, since the valuables are recoverable using other techniques (breaking up placer material in log washers, for instance). Most ores, however, are made up of hard, tough rock masses that must be crushed before the valuable minerals can be released.In order to produce a crushed material suitable for use as mill feed (100 percent of the pieces must be less than 10 to 14 millimetres, or 0.4 to 0.6 inch, in diameter), crushing is done in stages. In the primary stage, the devices used are mostly jaw crushers with openings as wide as two metres. These crush the ore to less than 150 millimetres, which is a suitable size to serve as feed for the secondary crushing stage. In this stage, the ore is crushed in cone crushers to less than 10 to 15 millimetres. This material is the feed for the grinding mill.

A crusher is a multi dimensional machine which is designed to reduce large size materials into smaller size materials. Crushers may be used to reduce the size, or change the form of waste materials so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials (as in the case of ore), so that pieces of different composition can be differentiated for separation.

Crushers are normally low speed machines that are designed for breaking large lumps of ores and stones, even a size with a diameter of over one and half meter. The purpose of crusher is to reduce the size of the materials for making them usable in construction or industrial use, or for extraction of valuable minerals trapped within a ore matrix.

Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed do. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in relation to (deformation), each other. There are four basic ways to reduce a material, namely (i) impact, (ii) attrition, (iii) shear, and (iv) compression. Most crushers employ a combination of all these crushing methods.

Crushers are classified into three types based upon the stage of crushing they accomplish. These are (i) primary crusher, (ii) secondary crusher, and (iii) tertiary crusher. The primary crusher receives material directly from run of mine (ROM) after blasting and produces the first reduction in size. The output of the primary crusher is fed to a secondary crusher, which further reduces the size of the material. Similarly the output of secondary crusher is fed to the tertiary crusher which reduces the material size further. Some of the materials may pass through four or more of the crushing stages before it is reduced to the desired size. The degree of crushing is spread over several stages as a means of closely controlling product size and limiting waste material.Crushers are also classified by their method of mechanically transmitted fracturing energy to the material. Jaw, gyratory and roll crushers work by applying compressive forces while impact crushers such as hammer crusher apply high speed impact force to accomplish fracturing.

Jaw crusher

Jaw crusher is used as primary crusher. It uses compressive force for breaking the material. This mechanical pressure is achieved by the two jaws of the crusher. Reduction ratio is usually 6:1. The jaw crusher is consisting of two vertical jaws installed to a V form, where the top of the jaws are further away from each other than the bottom.One jaw is kept stationary and is called a fixed jaw while the other jaw, called a swing jaw, moves back and forth relative to it, by a cam or pitman mechanism. The volume or cavity between the two jaws is called the crushing chamber. The movement of the swing jaw can be quite small, since complete crushing is not performed in one stroke. The inertia required to crush the material is provided by a weighted flywheel that moves a shaft creating an eccentric motion that causes the closing of the gap. Feed is entering to crusher from the top and lumps are crushed between jaws. Jaw crushers are heavy duty machines and hence need to be robustly constructed. The outer frame is generally made of cast iron or steel. The jaws themselves are usually constructed from cast steel. They are fitted with replaceable liners which are made of manganese steel, or Ni-hard (a Ni-Cr alloyed cast iron).Usually both jaws are covered with replaceable liners. Also in some types, the liners can be turned upside down after a while, extending the replacement time.

Classification of Jaw crusher

A jaw crusher uses compressive force for breaking of particle. This mechanical pressure is achieved by the two jaws of the crusher of which one is fixed while the other reciprocates. A jaw or toggle crusher consists of a set of vertical jaws, one jaw is kept stationary and is called a fixed jaw while the other jaw called a swing jaw, moves back and forth relative to it, by a cam or pitman. The volume or cavity between the two jaws is called the crushing chamber. The movement of the swing jaw can be quite small, since complete crushing is not performed in one stroke. The inertia required to crush the material is provided by a flywheel that moves a shaft creating an eccentric motion that causes the closing of the gap.Jaw crushers are heavy duty machines and hence need to be robustly constructed. The outer frame is generally made of cast iron or steel. The jaws themselves are usually constructed from cast steel. They are fitted with replaceable liners which are made of manganese steel, or Ni-hard (a Ni-Cr alloyed cast iron). Jaw crushers are usually constructed in sections to ease the process transportation if they are to be taken underground for carrying out the operations.

Jaw crushers are classified on the basis of the position of the pivoting of the swing jaw

1. Blake crusher-the swing jaw is fixed at the lower position
2. Dodge crusher-the swing jaw is fixed at the upper position

The Blake crusher was patented by Eli Whitney Blake in 1858. The Blake type jaw crusher has a fixed feed area and a variable discharge area. Blake crushers are of two types- single toggle and double toggle jaw crushers.

In the single toggle jaw crushers, the swing jaw is suspended on the eccentric shaft which leads to a much more compact design than that of the double toggle jaw crusher. The swing jaw, suspended on the eccentric, undergoes two types of motion- swing motion towards the fixed jaw due to the action of toggle plate and vertical movement due to the rotation of the eccentric. These two motions, when combined, lead to an elliptical jaw motion. This motion is useful as it assists in pushing the particles through the crushing chamber. This phenomenon leads to higher capacity of the single toggle jaw crushers but it also results in higher wear of the crushing jaws. These type of jaw crushers are preferred for the crushing of softer particles.In the double toggle jaw crushers, the oscillating motion of the swing jaw is caused by the vertical motion of the pitman. The pitman moves up and down. The swing jaw closes, i.e., it moves towards the fixed jaw when the pitman moves upward and opens during the downward motion of the pitman. This type is commonly used in mines due to its ability to crush tough and abrasive materials.

In the Dodge type jaw crushers, the jaws are farther apart at the top than at the bottom, forming a tapered chute so that the material is crushed progressively smaller and smaller as it travels downward until it is small enough to escape from the bottom opening. The Dodge jaw crusher has a variable feed area and a fixed discharge area which leads to choking of the crusher and hence is used only for laboratory purposes and not for heavy duty operations.

In the Blake or jaw crusher the **moveable jaw is pivoted at top**. The greatest amount of motion is at the bottom which means it has the little tendency to choke. ... In the dodge jaw crusher the moving jaw is pivoted at the bottom. As minimum movement is at the bottom it has a greater tendency to choke.