

Characteristics of Minerals

- Naturally occurring inorganic substances.
- Definite chemical composition.
- Crystalline structure.
- Solid state (except mercury ore).
- Formed by natural geological processes.
- Unique physical properties like hardness, color, luster, cleavage, etc.

Physical Properties of Minerals

- **Color** – visible appearance.
- **Streak** – color of powdered mineral.
- **Luster** – metallic or non-metallic shine.
- **Hardness** – resistance to scratching (Mohs scale).
- **Cleavage & Fracture** – manner of breaking.
- **Specific Gravity** – density compared to water.
- **Crystal Form** – geometric arrangement.
- **Tenacity** – resistance to breaking, bending, cutting.

Important Mineral Deposits in India

- **Iron ore** – Odisha (Keonjhar, Mayurbhanj), Chhattisgarh (Bailadila), Jharkhand.
- **Coal** – Jharkhand, Odisha, Chhattisgarh, West Bengal.
- **Bauxite** – Odisha, Gujarat, Jharkhand, Maharashtra.
- **Manganese** – Odisha, Karnataka, Madhya Pradesh.
- **Copper** – Rajasthan (Khetri), Madhya Pradesh (Balaghat), Jharkhand (Singhbhum).
- **Gold** – Karnataka (Kolar, Hutti).
- **Limestone** – Madhya Pradesh, Rajasthan, Andhra Pradesh.

Rock vs Mineral

- **Rock** – A natural aggregate of minerals (example: granite = quartz + feldspar + mica).
- **Mineral** – A naturally occurring inorganic substance with definite composition and structure.

Ore vs Mineral

- **Mineral** – A naturally occurring inorganic element/compound.
- **Ore** – A mineral deposit from which a metal can be economically extracted.
- Example:
 - **Bauxite** (ore of Aluminium).
 - **Hematite** (ore of Iron).

Types of Ore

- **Oxide ores** (e.g., Hematite Fe_2O_3).
- **Sulphide ores** (e.g., Galena PbS).
- **Carbonate ores** (e.g., Calcite CaCO_3).
- **Halide ores** (e.g., Rock salt NaCl).
- **Sulphate ores** (e.g., Barite BaSO_4).
- **Nitrate ores** (e.g., Chile saltpetre NaNO_3).

Mineral Processing

1.2.1 Advantages

- Increases metal recovery.
- Improves ore grade and quality.
- Reduces transportation cost (removing gangue).
- Provides raw material for metallurgical processes.
- Enhances economic value of ore.

Principle Operations in Mineral Processing

- a. **Comminution** – Crushing and grinding to reduce ore size.
- b. **Sizing** – Separation of particles based on size (screening, classification).
- c. **Concentration** – Separation of valuable minerals from gangue (gravity separation, flotation, magnetic separation).
- d. **Dewatering** – Removal of water from concentrate (filtration, drying).
- e. **Agglomeration** – Binding fine particles into larger lumps/pellets for easier handling and processing.

Comminution and Degree of Liberation

- **Comminution:** The process of reducing large solid materials (ores) into smaller pieces to liberate valuable minerals from the gangue (waste rock).
- **Degree of liberation:** Refers to the percentage of valuable mineral grains that are freed from gangue after comminution. A high degree of liberation is necessary for efficient separation in further processes (like flotation or gravity separation).

Crushing

Crushing is the first stage of comminution where ore size is reduced from large lumps to smaller particles.

Laws of Reduction

1. Rittinger's Law

- States that energy required for size reduction is proportional to the new surface area generated.
- Suitable for **fine grinding**.
- $E \propto \Delta S$

2. Kick's Law

- Energy required is proportional to the size reduction ratio (initial size to final size).
- Suitable for **coarse crushing**.
- $E \propto \ln\left(\frac{D_1}{D_2}\right)$

3. Bond's Law

- A practical law combining the concepts of Rittinger and Kick.
- Energy required is proportional to the reduction in the square root of particle size.
- Used in **industrial design of crushers and mills**.
- $E \propto \left(\frac{1}{\sqrt{D_2}} - \frac{1}{\sqrt{D_1}}\right)$

Types of Crusher

1. Jaw Crusher

- Uses compressive force.
- Consists of two jaws (one fixed, one moving).
- Suitable for **primary crushing**.

2. Gyratory Crusher

- Similar principle to jaw crusher but with a conical crushing head that gyrates inside a shell.
- Suitable for **large-scale primary crushing**.

3. Crushing Rolls (Roll Crusher)

- Two rolls rotate towards each other, crushing the ore between them.
- Used for **secondary crushing** and producing fine particles.

Jaw Crusher – Working Principle and Types

- **Working principle:**
 - Ore is fed into the top between two jaws.
 - The moving jaw compresses material against the fixed jaw, breaking it into smaller sizes.
- **Types:**
 1. Blake Jaw Crusher (pivot at top).
 2. Dodge Jaw Crusher (pivot at bottom).
 3. Universal Jaw Crusher (pivot at intermediate position).

Working Principle

1. Gyratory Crusher

- Crushing head gyrates inside a fixed shell.
- Continuous crushing action (unlike intermittent jaw crusher).
- Produces finer product in large capacity operations.

2. Crushing Rolls

- Material is pulled between two rotating rolls.
- Size reduction by compression and shear.
- Adjustable gap controls product size.

Grinding and Types of Grinding Mills

Grinding is the second stage of comminution where ore is further reduced to fine particles, usually < 0.1 mm.

Hammer Mill

- Uses high-speed rotating hammers to impact and shatter material.
- Suitable for brittle materials.
- Produces fine product.

Rolling Compression Mills

1. Ball Mill

- Rotating cylinder partly filled with steel balls.
- Balls cascade and grind ore by impact and attrition.
- Widely used for fine grinding.

2. Rod Mill

- Similar to ball mill but uses rods instead of balls.
- Produces coarser product than ball mill.

Attrition Mill

- Grinding occurs due to **rubbing and shear forces** between particles and surfaces.
- Used for **very fine powders**.

Tumbling Mill

- General term for mills that rotate and cause grinding media (balls/rods) to tumble.
- Includes ball mill, rod mill, pebble mill.
- Grinding action is a combination of impact and attrition.

Sieving

- **Definition:**
Sieving is a process of separating particles based on their size using a sieve or screen.
- **Mesh Concept:**
 - A **mesh** refers to the number of openings per linear inch in a screen.
 - Example: A 200-mesh screen has 200 openings per inch.
 - Higher mesh number = finer openings.
- **Sieving Process:**
Material is passed through a screen.
 - Particles **smaller than the openings** pass through.
 - Particles **larger than the openings** remain on top.

Screening

- **Concept:**
Screening is the mechanical process of separating material into two or more size fractions using a screen surface.
 - Oversize: Particles retained on the screen.
 - Undersize: Particles that pass through the screen.
- **Types of Screening:**
 1. **Dry Screening** – Screening without water (used for coarse materials).
 2. **Wet Screening** – Screening with water to improve separation efficiency.
- **Screening Process:**
 - Material is fed onto a screen surface.
 - Vibration, gravity, or motion helps particles stratify.
 - Fine particles move downward and pass through openings, coarse particles remain above.

Criteria for Selection of Sieving/Screening Process

1. **Particle size and shape**
2. **Moisture content** of material
3. **Capacity required** (tonnage per hour)
4. **Type of feed material** (hard, soft, sticky, abrasive)
5. **Accuracy of separation** required
6. **Economic factors** (cost and maintenance)

Working Principle and Types of Screens

- **Working Principle:**
Screens work on the principle of allowing smaller particles to pass through openings while retaining larger ones. Vibration or motion improves efficiency by reducing clogging and stratifying particles.
- **Types of Screens:**
 1. **Vibrating Screens:**
 - Work on vibration generated by electric motor or mechanical drive.
 - Types:
 - Circular Vibrating Screen
 - Linear Vibrating Screen
 - Banana Screen
 2. **Non-Vibrating Screens:**
 - Stationary or manually operated.
 - Types:

- Grizzly Screen (used for coarse separation)
- Revolving/ Trommel Screen (cylindrical rotating screen)

Factors Affecting Screening Performance

1. **Feed rate and uniformity**
2. **Moisture and stickiness of material**
3. **Particle shape** (round, flat, irregular)
4. **Screen opening size and shape**
5. **Screen inclination and vibration intensity**
6. **Wear and blinding (clogging) of screen surface**
7. **Operating conditions** (wet/dry screening)

Classification

Types of Classifiers

Classifiers separate particles based on size, shape, or specific gravity using fluid medium (air or water).

- **Types:**
 1. Hydraulic Classifier
 2. Rake Classifier
 3. Spiral Classifier
 4. Centrifugal Classifier
 5. Pneumatic/Air Classifier

Hydraulic and Rake Classifier

1. **Hydraulic Classifier**
 - Works on the principle of **differential settling velocity** of particles in water.
 - Fine/light particles are carried away with water overflow.
 - Coarse/heavy particles settle at the bottom.
 - Used in mineral processing and coal washing.
2. **Rake Classifier**
 - Consists of a sloping tank with a slowly moving **rake mechanism**.
 - Coarse/heavy particles settle at the bottom and are moved upward by the rake.
 - Fine/light particles overflow with water.
 - Common in grinding circuits for closed-loop classification.

Principle and Operation

- **Principle:**

Froth flotation is a concentration process used in mineral processing to separate valuable minerals from gangue.

 - It works on the principle of **differences in surface properties** of minerals.
 - Some minerals are **hydrophobic** (water-repelling) while others are **hydrophilic** (water-attracting).
 - By using reagents and air bubbles, hydrophobic minerals attach to air bubbles and rise to the surface to form a **froth**, while hydrophilic particles remain in water.
- **Operation (Steps):**
 1. **Crushing & Grinding** – Ore is ground to fine particles.
 2. **Pulping** – The ground ore is mixed with water to form slurry.
 3. **Reagent Addition** – Collectors, frothers, and other chemicals are added.
 4. **Aeration** – Air is introduced; bubbles form in the slurry.
 5. **Froth Formation** – Valuable minerals attach to bubbles and rise.
 6. **Collection** – Froth containing ore is skimmed off, leaving gangue behind.

Types of Reagents Used in Froth Flotation

1. **Collectors** – Make mineral surfaces hydrophobic (e.g., xanthates, fatty acids).
2. **Frothers** – Help form a stable froth (e.g., pine oil, cresols).
3. **Depressants** – Prevent unwanted minerals from floating (e.g., sodium cyanide, sodium silicate).
4. **Activators** – Increase the floatability of certain minerals (e.g., copper sulfate for sphalerite).
5. **Modifiers / Regulators** – Control pH and improve selectivity (e.g., lime, sulfuric acid).

Magnetic and Electrostatic Separation Process

- **Magnetic Separation:**
 - Based on differences in **magnetic properties** of minerals.
 - Strongly magnetic minerals (e.g., magnetite, hematite) are separated from non-magnetic minerals (e.g., quartz).
 - Types:
 - Low-intensity magnetic separators (for strongly magnetic ores).
 - High-intensity magnetic separators (for weakly magnetic ores).
- **Electrostatic Separation:**
 - Based on differences in **electrical conductivity** of minerals.
 - Conductive minerals (e.g., metallic minerals) lose their charge easily and fall, while non-conductive minerals stick to the charged surface.
 - Used for separating rutile, zircon, monazite, etc.

Dewatering and Drying

- After concentration, the mineral slurry still contains large amounts of water.
- **Dewatering:** Removal of water from the ore concentrate by methods such as:
 - **Thickening** – Using thickeners/settling tanks.
 - **Filtration** – Using vacuum filters or pressure filters.

- **Centrifugation** – Spinning to separate water.
- **Drying:** Final removal of moisture using:
 - **Rotary dryers, fluidized bed dryers, or spray dryers.**
 - Ensures the concentrate is dry and suitable for transport and further use.

Sintering – Concept

- **Concept:**
Sintering is the process of heating fine particles of ore (or other materials) below their melting point, so that they stick together and form a porous, hard mass called a *sinter*.
- It is mainly used in iron ore preparation to convert fine ores and concentrates into a strong agglomerate that can be used in the blast furnace.

Pelletising – Concept

- **Concept:**
Pelletising is the process of converting very fine iron ore powder into spherical balls (pellets) of uniform size, usually 8–18 mm diameter.
- The fine ore particles are mixed with binders (like bentonite clay) and rolled into balls, which are then heat-hardened.
- Pellets are strong, uniform, and allow better permeability in the blast furnace.

Briquetting – Definition and Principle

- **Definition:**
Briquetting is the process of compressing fine materials (ore fines, coal dust, or other powders) into large, solid blocks or briquettes without melting them.
- **Principle:**
It works on the principle of applying **mechanical pressure** (sometimes with binders) to compact fine particles into a dense mass. This improves handling, storage, and furnace performance.

Nodulizing – Definition and Principle

- **Definition:**
Nodulizing is the process of heating fine ores in a rotary kiln to produce small, hard, rounded lumps called *nodules*.
- **Principle:**
It is based on **partial fusion and recrystallization** of ore fines at high temperature, which causes them to agglomerate into nodules. This process improves the metallurgical properties of ores.

Vacuum Extrusion – Concept and Principle

- **Concept:**
Vacuum extrusion is the process of shaping fine materials (such as ore concentrates, clay, or ceramics) into briquettes or blocks by forcing them through a die under vacuum conditions.
- **Principle:**
It works on the principle of **removing air and moisture under vacuum** while applying pressure, so the compacted material has high density, strength, and uniformity.