

Mineralogy Lectures

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MINERALS AND MINERALOGY

A mineral is a naturally occurring crystalline solid with a definite but not fixed chemical composition and definite crystal structure. It is usually formed by inorganic processes.

Each paragraph of the definition is discussed as follows:

- Naturally occurring: We mean that the minerals are formed without the intervention of human action. Sometimes minerals can be synthesized in the laboratory. These materials are called “synthetic minerals”.
- Crystalline solid with a definite crystal structure: We mean that the minerals have a systematic arrangement of atoms and/or ions, and they are chemically bound in a regular and repeated pattern. The beautiful symmetrically arranged crystal faces in many minerals are a result of this internal arrangement of the atoms and ions. Solids such as glass have no internal atomic arrangement and so have no systematic structure; hence, they are not considered minerals, and they are called amorphous solids.
- A definite but not fixed chemical composition: We mean that the chemical composition may change within a limit, for example, the olivine mineral, which has the composition $(\text{Mg, Fe})_2\text{SiO}_4$ but this mineral may form a series where sometimes it will be Mg-rich so its composition will be Mg_2SiO_4 (Forsterite), sometimes it will be Fe-rich so its composition will be Fe_2SiO_4 (Fayalite), and sometimes it has an intermediate composition between these two end members, that is $(\text{Mg, Fe})_2\text{SiO}_4$.
- Part of the definition of a mineral is that they are “inorganic”, but many are produced by organic processes; for example, the shells of many marine invertebrates are formed of calcite or aragonite (CaCO_3) or apatite $\text{Ca}_5(\text{PO}_4)_3$, which makes teeth and bones of the vertebrates. Bacteria may be involved in many geologic and geochemical processes which produce coal beds, oil, etc.
- Because minerals are crystalline solids, they have definite physical properties.

Mineralogy is the scientific discipline concerned with the study of minerals from the following perspectives:

1. Description
2. Chemical composition.
3. Classification and genesis.

Physical Properties of Minerals

1- Color

The color of a mineral is produced as a result of absorption of certain wavelengths and reflection the others. Dark-colored minerals mean that the mineral absorbed all wavelengths of light. Green-colored minerals mean that these minerals absorbed all wavelengths of the light and reflected the green light only.

There are different causes for the color in minerals:

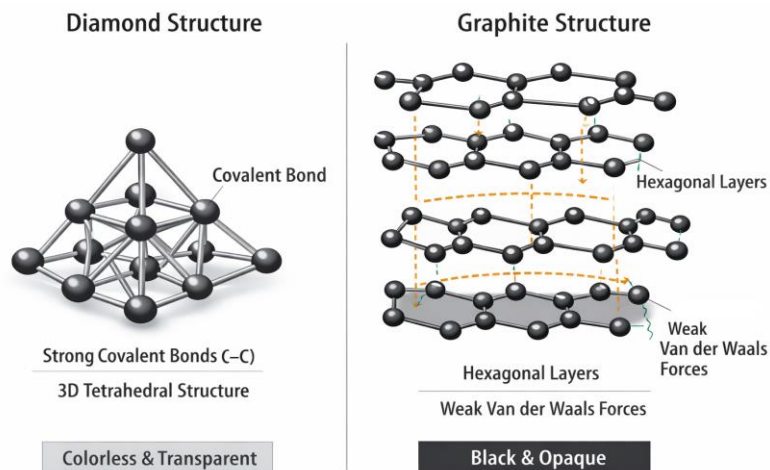
a. Color may be a fundamental property related directly to the chemical composition of the mineral.

- Hematite is red to brown in color due to the presence of iron (Fe) in its chemical composition.

- Malachite has a green color because of the presence of copper (Cu) in its composition.

-Sulfur is yellow in color because it is composed mainly of the element sulfur (S).

b. Color may be dependent on crystal structure and bond type, as in the polymorph of carbon (diamond and graphite), where diamond is colorless and transparent whereas graphite is black and opaque.



c. Sometimes color is due to some impurities in the mineral. Examples: Quartz is generally colorless when pure; some varieties show coloration due to the presence of some impurities. Amethyst (a purple variety of quartz) obtains its color due to the presence of iron impurities (Fe^{3+}) combined with natural irradiation, which produces color centers responsible for the violet color. Rose quartz is pink due to the presence of trace impurities such as iron (Fe^{2+}) or titanium (Ti). Smoky quartz is brown to gray color due to the presence of aluminum (Al) impurities within the crystal lattice, together with natural irradiation, which creates color centers responsible for the smoky appearance. Minerals which have a constant and characteristic color are called 'idiochromatic', while those whose colors are variable are called 'allochromatic'.

Idiochromatic minerals have a constant and characteristic color that is directly related to their essential chemical composition.

The color is caused by elements that are an integral part of the mineral's chemical structure.

Examples:

Malachite: Green color due to copper (Cu^{2+}) in its chemical composition.

Azurite: Blue color due to copper (Cu^{2+}).

Hematite: Red to brown color due to iron (Fe^{2+}).

In these minerals, the color is stable and typical of the mineral itself.

Allochromatic minerals have variable colors caused by impurities, trace elements, or structural defects, not by their main chemical composition.

The same mineral can appear in different colors depending on the impurities present.

Examples:

Quartz (colorless in pure form)

Amethyst: Purple color due to iron impurities (Fe^{3+}) and natural irradiation.

Rose Quartz: Pink color due to iron (Fe^{2+}) or titanium (Ti) impurities.

Smoky Quartz: Brown to gray color due to aluminum (Al) impurities and irradiation.

In allochromatic minerals, the color is not fixed and may vary.

2- Streak

The streak is the color of a mineral's fine powder, determined by rubbing the mineral on a piece of white porcelain surface called a streak plate.

Example:

Hematite has black color and red streak.

Magnetite has black color and black streak.

3- Luster

The luster is the reflection of light from the mineral surfaces.

Three main types of lusters are recognized in the minerals:

- a. Metallic:** Opaque mineral (black or very dark streak).
- b. Submetallic:** Intermediate luster. A submetallic luster often occurs in near-opaque minerals.
- c. Nonmetallic:** Light color (colorless or very light streak).
 - 1. Vitreous (Example: Quartz).
 - 2. Resinous (Example: Sulfur).
 - 3. Pearly (Example: Gypsum-alabaster).
 - 4. Greasy (Example: Talc).
 - 5. Silky (Example: Fibrous Gypsum).
 - 6. Adamantine (Example: Diamond).
 - 7. Earthy (Example: Kaolinite).

4- Transparency

It is transmitted light within the mineral.

There are three types of the minerals:

- a. Transparent** (Example: Quartz, Gypsum)
- b. Translucent** (Example: Smoky Quartz)
- c. Opaque** (Example: Galena, Graphite)

5- Hardness (H)

The mineral surface's resistance to scratching.

The degree of hardness is determined by:

- a.** Mineral hardness is evaluated by observing the ability of one mineral to scratch another.
- b.** Mineral hardness is determined using the Mohs scale of hardness:

- | | | | | |
|---------------|-----------|------------|-------------|-------------|
| 1. Talc | 2. Gypsum | 3. Calcite | 4. Fluorite | 5. Apatite |
| 6. Orthoclase | 7. Quartz | 8. Topaz | 9. Corundum | 10. Diamond |

c. Mineral hardness is determined using some simple tools:

Tools	Hardness
Pencil	1.5
Fingernail	2.5
Copper coin	3.5
Steel knife	5.0-5.5
Window glass	5.5
Steel nail	6.5
Steel file	6.7
Streak plate	6.5-7.0
Masonry drill bit	8.5

6- Cleavage

The cleavage is the split of a mineral along regular planes. Cleavage is always parallel to certain crystal faces and related to the internal structure. Minerals with cleavage mean that the bonding along with the planes of the cleavage is weaker because cleavage planes are considered “planes of weakness”. Minerals with no cleavage in general are harder than those which have cleavage.

Type of cleavage:

Number of sets	Description	Example
One	Basal cleavage	Mica
Two	Prismatic cleavage (Perpendicular)	Pyroxene
Two	Prismatic cleavage (Oblique)	Amphibole
Three	Cubic cleavage	Halite
Three	Rhombohedral cleavage	Calcite
Four	Octahedral cleavage	Fluorite

Cleavage is described as:

1. Perfect.
2. Distinct or good.
3. Imperfect.
4. None or poor.

7- Fracture

Fracture is irregular breakage of a mineral.

Type of fracture:

1. Even.
2. Uneven.
3. Hackly.
4. Earthy.
5. Conchoidal.

8- Specific gravity (G) or relative density

The number expresses the ratio between the weight of a substance and the weight of an equal volume of water at 4°C.

Different methods are used to determine the density of the minerals. One of these methods is by using heavy liquids. The mineral grains are immersed in a suitable heavy liquid, and we notice whether these grains sink or float. If the grains sink, that means the density of this mineral is higher than the density of this liquid, and if they float, that means their density is lower than that liquid.

Heavy liquids are liquids that have high density and specific gravity and are used to determine the densities of minerals relatively and also in the separation of mineral grains within any rock. There are different kinds of heavy liquids among them:

Bromoform (CHBr_3): $G = 2.89-2.90$, Acetylene tetrabromide ($\text{C}_2\text{H}_2\text{Br}_4$): $G = 2.94-2.96$, Methylene iodide (CH_2I_2): $G = 3.32-3.33$, and Clerici solution: $G = 4.00-4.25$.

The traditional method to determine specific gravity is using your hand, so the minerals are divided into the following:

Heavy minerals ($G > 2.9$)

Light minerals ($G < 2.9$).

9- Special Properties of Minerals

a. Magnetism:

Minerals are divided into three groups according to their magnetic properties:

1. Ferromagnetic minerals: Strongly attracted by a magnet. Example: Magnetite Fe_3O_4 .
2. Paramagnetic minerals: Slightly attracted to a magnet. Example: Hematite Fe_2O_3 .
3. Diamagnetic minerals: Minerals repelled by a magnet. Example: Quartz SiO_2 .

b. Taste:

1. Saline: Example: Halite NaCl .
2. Bitter: Example: Sylvite KCl .

c. Feel:

1. Smooth: Example: Agate, Flint.
2. Harsh: Example: Chromite.
3. Greasy: Example: Talc, Gypsum.

d. Odor:

1. Argillaceous: Example: Kaolinite.
2. Sulphurous: Example: Pyrite FeS_2 .

e. Acid reaction: Some carbonate minerals react with hydrochloric acid. Example: Calcite CaCO_3 .

f. Electrical properties

It can be classified into two groups of minerals:

1. Conductor: Those minerals with metallic bonding, such as the native metals and some sulphide minerals.
2. Non-conductor: May induce electrical charge by change in temperature (pyroelectricity) or pressure (piezoelectricity).

g. Radioactivity

Radioactivity in minerals is related to the presence of some radioactive elements such as uranium (U), thorium (Th), potassium (K), and rubidium (Rb), which are radioactive isotopes and disintegrate at a constant rate. This disintegration is accompanied by three types of radiation: alpha, beta, and gamma. This property, if present in a mineral, is useful in calculating the age of the rock that contains that mineral.