Minerals, Mineralogy, Physical properties

Objectives

- Definition of mineral
- Mineralogy: its significance, scope, and methods
- Physical properties of minerals and mineral identification in hand specimens

Definition of mineral

The definition of mineral includes the following criteria
- Naturally occurring
- Solid with highly ordered atomic arrangement
- Definite (but not fixed) chemical composition
- Usually formed by inorganic processes

There are more than 4000 known mineral species.

Mineralogy: its significance, scope, and methods

Why do we study minerals?
- Minerals are living necessities and economically important
- Mineralogy is a fundamental part of Earth sciences. It is the basis for petrology, structural geology and tectonics, geochemistry, geophysics, environmental science, and planetary science.
- Many people are fascinated by the beauty and power of gemstones.

Mineralogy consists of several branches.

- Crystallography deals with the geometric forms of minerals at the macro-scale and the underlying structures of minerals at the micro-scale.
- Mineral physics covers physical properties of hand specimens and optical properties of grain mounts and thin sections.
- Crystal chemistry investigate the composition, bonding forces, stability, reactions of minerals and synthetic crystals.
- Systematic mineralogy provides a scheme of classification and detailed descriptions of the occurrence and use of various minerals.

The study of minerals can be traced back to the Stone Age, about 5000 years ago. The following are some of the important milestones in mineralogy:

- during the 17 to 18th century, Steno used ruler and goniometer to study the regular external shape of minerals in a quantitative way. Haüy came up with the concept of integral molecules (equivalent to “unit cells” in modern term) as building blocks of minerals.
- In the 19th century, polarizing microscope was used to study the internal symmetry and order of minerals.
- In the 20th century, Laue and Bragg developed x-ray diffraction technique, which allows investigation of internal order at the atomic level.

Modern mineralogy is an active and fast-growing field. The invention of electron microscopy, synchrotron x-ray scattering, neutron diffraction, Raman, Infrared, and Brillouin spectroscopy has opened up many new frontiers for studying the composition, structure, and properties of minerals at micron to nano scales. Vast literature, database, and visualization software have become available and are growing at unprecedented pace. The subject of mineralogy has been broadened.

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to include synthetic crystals produced in laboratory (silicate perovksite in deep Earth studies, zeolite for industrial applications), amorphous phases (high pressure melts in Earth and planetary interiors), and reactions at mineral surface and/or involving micro-organism (geomicrobiology, astrobiology).

Physical properties of minerals and mineral identification in hand specimens

Mineral specimens: Commonly used mineral specimens include hand specimens, grain mounts and thin sections. The physical properties of hand specimens can be examined through visual observation and various simple physical and chemical tests.

Geometric Features

The geometric features of a single crystal are described in terms of crystal habit and crystal form.

- Crystal habit denotes the external shape of a crystal. The terms to describe the quality of crystal include euhedral, subhedral, and anhedral.
- In crystallography, the term “form” is used in a restricted sense. A form refers to a group of crystal faces, all of which have the same relation to the elements of symmetry that are inherent in the crystal. Common forms include cube (pyrite, rock salt), octahedron (diamond), hexagonal dipyramid (quartz).

For euhedral crystals, the form names are used to describe their habit. For example, cubic, octahedral.

- Certain minerals grow as twins. Twinning and intergrowth of two forms can produce parallel lines on crystal faces, called striation. Striation is commonly seen on pyrite samples.
- Most minerals occur as random aggregates of grains in the rock of the Earth. The state of aggregation is determined by the composition and structure of the minerals and their growth conditions. Common terms that are used to describe the state of aggregates include massive (sulfur), geode (quartz), lamellar (mica), colloform (stalactite).

Optical Properties

The optical properties of minerals include color, streak, luster, transparency, iridescence, luminescence, fluorescence, and phosphorescence.

Tip: To identify a mineral based on its optical properties, it is important to examine a fresh surface.

- Luster refers to the appearance of a mineral surface in reflected light. Metallic luster is the luster of metallic surface such as gold, copper, steel. Many sulfides such as Galena and Pyrite also show metallic luster. Non-metallic luster include vitreous (olivine), greasy (quartz), silky (asbestos).
- Color is a striking feature of minerals. Some minerals have characteristic colors. For instance, sulfur (yellow), gold (golden), Amethyst (purple). Minerals with metallic luster usually have characteristic colors. For examples, sulfides are relatively easy to diagnose from their colors. However, the colors of minerals with non-metallic luster can vary within the same mineral, as their colors are often controlled by minor or trace element concentrations. For example, Corundum can be sapphire (blue) or ruby (red).
- Streak is the color of fine powder. You need a streak plate to see the streak. Streak is commonly useful for identifying dark metallic minerals. For example, hematite has a characteristic red streak.
- Transparency describes the capability of a mineral to transmit light. A mineral can be transparent, translucent, or opaque. Most gem minerals are highly transparent. Most metallic minerals are opaque.
- Iridescence, also known as play of color, describes the phenomenon that the color of a mineral changes with the angle of the incident light. Internal iridescence (e.g. opal) is caused by
interference of light reflected from closely spaced fractures, cleavage planes, twin lamellae, exsolution lamellae, or minute foreign inclusions in parallel orientation. Surface iridescence (e.g. hematite) is caused by interference of light reflected from thin surface films produced by oxidation or alteration.

- Fluorescence describes the phenomenon that a mineral emit light during exposure to ultraviolet, x-ray, or cathode rays. The usual blue fluorescence of Fluorite may result from the presence of rare earth ions. The pale blue fluorescence of most scheelite (CaWO₄) is ascribed to molybdenum substituting for tungsten. The brilliant fluorescence of willemite (Zn₂SiO₄) and calcite from Franklin, NJ, is attributed to the presence of manganese.
- Phosphorescence refers to the emission of light by a mineral after exposure to excitation.

Mechanical properties
The mechanical properties of minerals are usually determined through destructive tests. Non-destructive tests include specific gravity and thermal conductivity.

- Cleavage, parting, and fracture are the response of a mineral under stress.
  > Cleavage is the tendency of minerals to break parallel to atomic planes. Cleavage results from different strength of chemical bonding in different directions. The quality of cleavage can be perfect, good, fair, or poor.
  > Parting describes mineral breaking along planes of structural weakness that is caused by twinning, exsolution, etc.
  > Fracture is the way minerals break when they do not yield along cleavage or parting surfaces. For example, conchoidal (Quartz), fibrous, hackly, irregular.
- Hardness describes the resistance of a mineral surface to scratching. It reflects the strength of chemical bonding. Hydrous minerals, halides, carbonates, sulfates, phosphates, sulfides are relatively soft (usually H<5), anhydrous oxides and silicates are relatively hard (H>5). As hardness is determined by the weakest bonding in the structure, silicates have hardness ranging from 1 to 8.
  > Mohs scale of hardness is a relative scale. 1 talc (baby powder), 2 gypsum, 3, calcite (scratched all over), 4 fluorite (state mineral of Illinois), 5 apatite (teeth), 6 orthoclase, 7 quartz (harder than window glass), 8 topaz, 9 corundum (sapphire, ruby), 10 diamond (cutting, grinding industry and high-pressure research).
- Tenacity is the resistance of a mineral to breaking, crushing, bending, or tearing. Common terms used to describe tenacity include brittle (e.g. MgO, LaCrO₃, Re-W thermocouple), malleable (gold), ductile (Pt wires, Mo wires).
- Specific gravity is the density of a mineral relative to that of water at 4 °C. It depends on the chemical composition and crystal structure of the mineral.

Other properties
- Paramagnetic minerals are attracted to a magnet.
- Minerals containing uranium(U) and thorium (Th) undergo decay reaction.
- Carbonates bubbles in diluted HCl (effervescence)
- Pressure induces electrical charge (piezoelectricity)

Minerals of the Week
diamond, graphite, gold, platinum

Optional questions:
? Why is diamond so much harder than graphite?
? Why is diamond a perfect insulator while graphite an excellent conductor?
? Why are gold and platinum so malleable?