

EENS 2110	Mineralogy
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Physical Properties of Minerals	

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Although we have discussed x-ray identification of minerals and later in the course will discuss techniques that can be used to identify minerals with the optical microscope, it is still necessary to develop techniques that can be used in the laboratory and field where instrumentation like x-ray diffractometers or microscopes cannot be easily used. Minerals have distinguishing physical properties that in most cases can be used to determine the identity of the mineral. In this course, you will develop a systematic approach to using the physical properties of minerals as identifying tools. If you follow this approach you should be able to identify most of the common minerals, or at the least be able to narrow the possibilities to only a few. We will first discuss each of the physical properties that can be used, then develop a methodical approach to the identification of minerals using these physical properties. Among the properties we will discuss are: crystal habit, cleavage, hardness, density, luster, streak, color, tenacity, magnetism, and taste.

Crystal Habit

In nature perfect crystals are rare. The faces that develop on a crystal depend on the space available for the crystals to grow. If crystals grow into one another or in a restricted environment, it is possible that no well-formed crystal faces will be developed. However, crystals sometimes develop certain forms more commonly than others, although the symmetry may not be readily apparent from these common forms. The term used to describe general shape of a crystal is *habit*.

Some common crystal habits are as follows (discussed previously):

Individual Crystals

- *Cubic* - cube shapes
- *Octahedral* - shaped like octahedrons, as described above.
- *Tabular* - rectangular shapes.
- *Equant* - a term used to describe minerals that have all of their boundaries of approximately equal length.
- *Acicular* - long, slender crystals.
- *Prismatic* - abundance of prism faces.
- *Bladed* - like a wedge or knife blade.

Groups of Distinct Crystals

- *Dendritic* - tree-like growths.
- *Reticulated* - lattice-like groups of slender crystals.
- *Radiated* - radiating groups of crystals.
- *Fibrous* - elongated clusters of fibers.
- *Botryoidal* - smooth bulbous or globular shapes.
- *Globular* - radiating individual crystals that form spherical groups.
- *Drusy* - small crystals that cover a surface.
- *Stellated* - radiating individuals that form a star-like shape.

Some minerals characteristically show one or more of these habits, so habit can sometimes be a powerful diagnostic tool.

Cleavage, Parting, and Fracture

Cleavage

Crystals often contain planes of atoms along which the bonding between the atoms is weaker than along other planes. In such a case, if the mineral is struck with a hard object, it will tend to break along these planes. This property of breaking along specific planes is termed cleavage. Because cleavage occurs along planes in the crystal lattice, it can be described in the same manner that crystal forms are described. For example if a mineral has cleavage along $\{100\}$ it will break easily along planes parallel to the (100) crystal face, and any other planes that are related to it by symmetry. Thus, if the mineral belongs to the tetragonal crystal system it should also cleave along faces parallel to (010), because (100) and (010) are symmetrically related by the 4-fold rotation axis. The mineral will be said to have two directions of cleavage. [Note that in the tetragonal system, the form $\{100\}$ has four faces: (100), $(\bar{1}00)$, (010), and $(0\bar{1}0)$. But if we are referring to cleavage directions, the mineral only has two, because the cleavage planes (0 $\bar{1}$ 0) and $(\bar{1}00)$ are parallel to, and thus in the same direction as (010) and (100).]

The cleavage can also be described in terms of its quality, i.e., if it cleaves along perfect planes it is said to be perfect, and if it cleaves along poorly defined planes it is said to be poor.

Note: Please do not attempt to cleave the minerals in the laboratory. Many of the specimens you examine cannot be readily replaced. Cleavage is usually induced in the mineral when it is extracted from the rock when it is found, and can usually be seen as planes running through the mineral. Therefore, you do not have to break the mineral in order to see its cleavage.

Cleavage can also be described by general forms names, for example if the mineral breaks into rectangular shaped pieces it is said to have cubic cleavage (3 cleavage directions), if it breaks into prismatic shapes, it is said to have prismatic cleavage (2 cleavage directions), or if it breaks along basal pinacoids(1 cleavage direction) it is said to have pinacoidal cleavage. For

examples, see figure 2.12 on page 29 of your text.

Parting

Parting is also a plane of weakness in the crystal structure, but it is along planes that are weakened by some applied force. It therefore may not be apparent in all specimens of the same mineral, but may appear if the mineral has been subjected to the right stress conditions.

Fracture

If the mineral contains no planes of weakness, it will break along random directions called fracture. Several different kinds of fracture patterns are observed.

- Conchoidal fracture - breaks along smooth curved surfaces.
- Fibrous and splintery - similar to the way wood breaks.
- Hackly - jagged fractures with sharp edges.
- Uneven or Irregular - rough irregular surfaces.

Hardness

Hardness is determined by scratching the mineral with a mineral or substance of known hardness. Hardness is a relative scale, thus to determine a mineral's hardness, you must determine that a substance with a hardness greater than the mineral does indeed scratch the unknown mineral, and that the unknown mineral scratches a known mineral of lesser hardness.

Hardness is determined on the basis of Moh's relative scale of hardness exhibited by some common minerals. These minerals are listed below, along with the hardness of some common objects.

Hardness	Mineral	Common Objects
1	Talc	
2	Gypsum	Fingernail (2+)
3	Calcite	Copper Penny (3+)
4	Fluorite	
5	Apatite	Steel knife blade (5+), Window glass (5.5)
6	Orthoclase	Steel file
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

Several precautions are necessary for performing the hardness test.

- If you attempt to scratch a soft mineral on the surface of a harder mineral some of the softer substance may leave a mark of fine powder on the harder mineral. This should not be mistaken for a scratch on the harder mineral. A powder will easily rub off, but a

scratch will occur as a permanent indentation on the scratched mineral.

- Some minerals have surfaces that are altered to a different substance that may be softer than the original mineral. A scratch in this softer alteration product will not reflect the true hardness of the mineral. Always use a fresh surface to perform the hardness test.
- Sometimes the habit of the mineral will make a difference. For example aggregates of minerals may break apart leaving the impression that the mineral is soft. Or, minerals that show fibrous or splintery habit may break easily into fibers or splinters. It is therefore wise to always perform the hardness test in reverse. If one mineral appears to scratch another mineral, make sure that the other mineral does not scratch the apparently harder mineral before you declare which of the minerals is harder.
- In some minerals hardness is very dependant on direction, since hardness is a vectorial property. When there is significant difference in hardness in different directions, it can be a very diagnostic property of the mineral. It is thus wise to perform the hardness test by attempting to scratch the mineral in different directions. Two minerals of note have differences in hardness depending on direction:
 - Kyanite has a hardness of 5 parallel to the length of the crystal, and a hardness of 7 when scratched along a direction perpendicular to the length.
 - Calcite has a hardness of 3 for all surfaces except the {0001} plane. On {0001} it has a hardness of 2.

Tenacity

Tenacity is the resistance of a mineral to breaking, crushing, or bending. Tenacity can be described by the following terms.

- *Brittle* - Breaks or powders easily.
- *Malleable* - can be hammered into thin sheets.
- *Sectile* - can be cut into thin shavings with a knife.
- *Ductile* - bends easily and does not return to its original shape.
- *Flexible* - bends somewhat and does not return to its original shape.
- *Elastic* - bends but does return to its original shape.

Density (Specific Gravity)

Density refers to the mass per unit volume. Specific Gravity is the relative density, (weight of substance divided by the weight of an equal volume of water). In cgs units density is grams per cm^3 , and since water has a density of 1 g/cm^3 , specific gravity would have the same numerical value as density, but no units (units would cancel). Specific gravity is often a very diagnostic property for those minerals that have high specific gravities. In general, if a mineral has higher atomic number cations it has a higher specific gravity. For example, in the carbonate minerals the following is observed:

Mineral	Composition	Atomic # of Cation	Specific Gravity
Aragonite	CaCO_3	40.08	2.94
Strontianite	SrCO_3	87.82	3.78
Witherite	BaCO_3	137.34	4.31
Cerussite	PbCO_3	207.19	6.58

Specific gravity can usually be qualitatively measured by the heft of a mineral, in other words those with high specific gravities usually feel heavier. Most common silicate minerals have a specific gravity between about 2.5 and 3.0. These would feel light compared to minerals with high specific gravities.

For comparison, examine the following table:

Mineral	Composition	Specific Gravity
Graphite	C	2.23
Quartz	SiO_2	2.65
Feldspars	$(\text{K},\text{Na})\text{AlSi}_3\text{O}_8$	2.6 - 2.75
Fluorite	CaF_2	3.18
Topaz	$\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$	3.53
Corundum	Al_2O_3	4.02
Barite	BaSO_4	4.45
Pyrite	FeS_2	5.02
Galena	PbS	7.5
Cinnabar	HgS	8.1
Copper	Cu	8.9
Silver	Ag	10.5

Color

Color is sometimes an extremely diagnostic property of a mineral, for example olivine and epidote are almost always green in color. But, for some minerals it is not at all diagnostic because minerals can take on a variety of colors. These minerals are said to be allochromatic. For example quartz can be clear, white, black, pink, blue, or purple. Read in your textbook, pp. 234-241, about what causes minerals to have color.

Streak

Streak is the color produced by a fine powder of the mineral when scratched on a streak plate. Often it is different than the color of the mineral in non- powdered form

Luster

Luster refers to the general appearance of a mineral surface to reflected light. Two general types of luster are designated as follows:

1. ***Metallic*** - looks shiny like a metal. Usually opaque and gives black or dark colored streak.
2. ***Non-metallic*** - Non metallic lusters are referred to as
 - a. ***vitreous*** - looks glassy - examples: clear quartz, tourmaline
 - b. ***resinous*** - looks resinous - examples: sphalerite, sulfur.
 - c. ***pearly*** - iridescent pearl-like - example: apophyllite.
 - d. ***greasy*** - appears to be covered with a thin layer of oil - example: nepheline.
 - e. ***silky*** - looks fibrous. - examples - some gypsum, serpentine, malachite.
 - f. ***adamantine*** - brilliant luster like diamond.

Play of Colors

Interference of light reflected from the surface or from within a mineral may cause the color of the mineral to change as the angle of incident light changes. This sometimes gives the mineral an iridescent quality. Minerals that show this include: bornite (Cu_5FeS_4), hematite (Fe_2O_3), sphalerite (ZnS), and some specimens of labradorite (plagioclase).

Fluorescence and Phosphorescence

Minerals that light up when exposed to ultraviolet light, x-rays, or cathode rays are called fluorescent. If the emission of light continues after the light is cut off, they are said to be phosphorescent.

Some specimens of the same mineral show fluorescence while other don't. For example some crystals of fluorite (CaF_2) show fluorescence and others do not. Other minerals show fluorescence frequently, but not always. These include - scheelite (CaWO_4), willemite

(Zn_2SiO_4), calcite (CaCO_3), scapolite ($3\text{NaAlSi}_3\text{O}_8 \cdot (\text{NaCl} - \text{CaCO}_3)$), and diamond (C).

Magnetism

Magnetic minerals result from properties that are specific to a number of elements. Minerals that do not have these elements, and thus have no magnetism are called ***diamagnetic***. Examples of diamagnetic minerals are quartz, plagioclase, calcite, and apatite. Elements like Ti, Cr, V, Mn, Fe, Co, Ni, and Cu can sometimes result in magnetism. Minerals that contain these elements may be weakly magnetic and can be separated from each other by their various degrees of magnetic susceptibility. These are called ***paramagnetic*** minerals. Paramagnetic minerals only show magnetic properties when subjected to an external magnetic field. When the magnetic field is removed, the minerals have no magnetism.

Ferromagnetic minerals have permanent magnetism if the temperature is below the ***Curie Temperature***. These materials will become magnetized when placed in a magnetic field, and will remain magnetic after the external field is removed. Examples of such minerals are magnetite, hematite-ilmenite solid solutions ($\text{Fe}_2\text{O}_3 - \text{FeTiO}_3$), and pyrrhotite (Fe_{1-x}S).

Other Properties

Other properties that may be diagnostic include chatoyancy, asterism, piezoelectricity, and taste. Familiarize yourself with the meanings of these terms. And watch for these properties as you examine minerals.

Tables for Identification of Minerals

Beginning on page 604 of the Text by Klein and Dutrow are determinative tables which should aid you in using physical properties of minerals to identify them. Note that the tables are broken first into two different groups based on Luster. Within each group, the minerals are then further divided on the basis of streak, hardness, and cleavage. In the remarks column are listed other useful diagnostic property for each mineral. Again, I encourage you to develop a systematic approach to identifying minerals.

Luster - Metallic or Submetallic

- I. Hardness $< 2\frac{1}{2}$
- II. Hardness $> 2\frac{1}{2}$. $< 5\frac{1}{2}$.
- III. Hardness $> 5\frac{1}{2}$.

Luster - Nonmetallic

- I. Streak Colored
- II. Streak Colorless
 - A. Hardness $< 2\frac{1}{2}$
 - B. Hardness $> 2\frac{1}{2}$, < 3
 - 1. Cleavage prominent.
 - 2. Cleavage not prominent.
 - C. Hardness > 3 , $< 5\frac{1}{2}$.
 - 1. Cleavage prominent.
 - 2. Cleavage not prominent.
 - D. Hardness $> 5\frac{1}{2}$, < 7
 - 1. Cleavage prominent.

2. Cleavage not prominent.
- E. Hardness >7
 1. Cleavage prominent
 2. Cleavage not prominent.

Questions from this material that could be asked on an exam.

The use of physical properties to identify minerals will be necessary for the second lab exam, so you should become very familiar with using physical properties and the mineral identification charts to identify hand specimens of minerals. Other example questions that could appear on the lecture midterm are as follows:

1. Define the following: (a) cleavage, (b) parting, (c) fracture, (d) hardness, (e) luster, (f) streak, (g) density.
2. How are density and specific gravity related?
3. What factors control the density of a mineral?
4. What is the difference between paramagnetic, diamagnetic, and ferromagnetic minerals?

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