Lab 1 - Physical Properties and the Identification of Nonsilicate Minerals

All rocks are composed of one or more minerals. In order to be able to identify rocks you have to be able to recognize those key minerals that make of the bulk of rocks. By definition, any substance is classified as a mineral if it meets all 5 of the following criteria:

- is naturally occurring (ie. not man-made);
- solid (not liquid or gaseous);
- inorganic (not living and never was alive);
- crystalline (has an orderly, repetitive atomic structure);
- a definite chemical composition (you can write a discrete chemical formula for any mineral).

Identifying an unknown mineral is like identifying any group of unknowns (leaves, flowers, bugs... etc.) You begin with a box, or a pile, of unknown minerals and try to find any group features in the samples that will allow you to separate them into smaller and smaller piles, until you are down to a single mineral and a unique name. For minerals, these group features are called physical properties. Physical properties are any features that you can use your 5 senses (see, hear, feel, taste or smell) to aid in identifying an unknown mineral. Mineral physical properties are generally organized in a mineral key and the proper use of this key will allow you to name your unknown mineral sample. The major physical properties will be discussed briefly below *in the order in which they are used to identify an unknown mineral sample*.

Luster

Luster is the way that a mineral reflects light. There are two major types of luster; metallic and non-metallic luster. A mineral with a metallic luster has a very high metal content and is either shiny, because it reflects light like a polished piece of metal, or is dull- looking, because it reflects light like a metal rust or a metal tarnish. All other minerals that do not reflect light like some form of metal (i.e., that have a low metal content) are said to be nonmetallic. There are many sub groupings of nonmetallic luster and the terms for these lusters are very descriptive of their overall appearance; pearly, silky, waxy, dull, earthy, glassy (often called vitreous), resinous (like dried pine sap) are just a few examples.

Streak

A mineral's streak is the color of its powder when the mineral is rubbed on a square of porcelain called a streak plate. Streak is one of the best physical properties for the recognition of metallic minerals because metallic minerals all have a very dark-colored streak that is nearly always consistent for a given metallic mineral. Streak is, however, not a useful property for minerals that have a nonmetallic luster. Nonmetallic minerals have either a white streak or a very light-colored streak that is not consistent from one sample to the next. Also, some nonmetallic minerals are actually harder than the streak plate and thus can not be powdered.

Hardness

The hardness of a mineral is determined by scratching the mineral with a material of known hardness. The materials that Geologist's use to test mineral hardness are a set of minerals of known hardness called the Mohs Hardness Scale. There are ten minerals in the Mohs Hardness scale assigned numbers from 1 to 10, where 1 is the softest mineral possible and 10 is the hardest known mineral. Table X.X lists the Mohs Hardness Scale along with the hardness of several common mineral substitutes.

Minerals with a higher hardness number with scratch all minerals with a lower hardness numbers and *two minerals of the same hardness will scratch each other*. This is not a linear scale, that is, a mineral of hardness of 2 is not twice as hard as a mineral of hardness 1. What this means is that to test really hard minerals you have to use a good deal more force than for softer minerals. You must wipe off any mineral powder from the samples and examine them very closely to see which one (or even both if they have equal hardness numbers) was scratched. Also, do **NOT** use your jewelry to test mineral hardness! A diamond may be the hardest known mineral, but it is rather brittle and relatively easy to crush against even a softer mineral. Even if your diamond does survive a hardness test, the precious metal that diamonds are set in is quite soft and very easy to damage.

Hardness (H)	Mohs Mineral	Common Materials
1	Talc	
2	Gypsum	
2.5		Untreated Fingernail
3	Calcite	US Copper Penny (pre - 1982)
3.5		US Zinc Penny (after 1982)
4	Fluorite	
5	Apatite	Steel Nail
5 - 5.5		Pocket Knife
5.5		Glass Plate
6	Orthoclase	
6.5		Steel File
7	Quartz	
7.5		Streak Plate
8	Topaz	
9	Corundum	
10	Diamond	

Since even Geologists do not carry a pocket full of minerals in the field with them for testing purposes (and certainly not a large diamond), there are a few relatively common materials that will allow you to get a range of mineral hardnesses without having to purchase a Mohs Hardness scale set. A human fingernail has a very consistent hardness of 2.5. Any mineral that you can scratch with your fingernail is 2.5 or less in hardness. It must be emphasized that you should use an untreated fingernail, as some fingernail polishes and hardeners can be considerably harder than 2.5. In addition, any mineral of hardness of 1 will feel almost soapy when rubbed. Another common material used in hardness tests is a steel nail. Steel nails have a hardness of about 5. So, if you can not scratch a mineral with your untreated fingernail, but can scratch it with a steel nail than your mineral has a hardness range of greater then 2.5 but less than or equal to 5. (Note that many Geologists carry a pocket knife with them in the field since the blade of most pocket knives have a hardness that is close to a steel nail, i.e. 5 to 5.5). Finally, any mineral that will scratch a steel nail must have a hardness that is greater than 5. These three hardness categories have been simplified in a table below:

Can scratch with a fingernail	$H \leq 2.5$	Hardness is **Soft**
between a fingernail and a steel nail	$H > 2.5 \leq 5$	Hardness is **Medium**
can scratch a steel nail	$H > 5$	Hardness is **Hard**

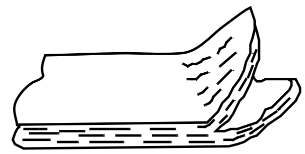
Cleavage and Fracture

Minerals are chemical compounds, which means that on an atomic level they are made up of atoms that are chemically bonded to each other. There are several possible types of chemical bonds that can be present in minerals. Some bonds may be weaker and others stronger. If a mineral contains weaker chemical bonds that are aligned, then these minerals will break along the planes of weakness created by these weaker chemical bonds. The ability of a mineral to break along smooth planes of weakness is a physical property called mineral cleavage (or just cleavage). Cleavage is a reproducible property, that is, if you see a smooth surface on a mineral and are able to reproduce that smooth surface by striking the mineral, then that smooth surface is known as a direction of cleavage. Minerals may have 1, 2, 3 or even 4 directions of cleavage (Figure 1). Note that a mineral actually has two smooth, parallel planes for each direction of mineral cleavage it contains (1 direction of cleavage yields 1 pair of parallel planes, 2 directions of cleavage yields 2 pairs of parallel planes,... etc.) A mineral which displays all of its surfaces of cleavage is called a cleavage fragment.

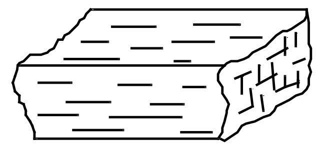
Some minerals lack cleavage and are said to have fracture instead. A fracture surface may appear either grainy and irregular like a piece of broken rock (an irregular fracture) or have very sharp and curved breaks like a piece of broken glass (i.e., a conchoidal fracture). Also note that there are different degrees (good, fair or poor) of cleavage possible in different mineral samples. Good cleavage means that a mineral has readily visible, smooth cleavage surfaces upon breaking. Fair cleavage means that some samples may show all of their cleavage surfaces while others may not show their cleavage well. Poor cleavage means that smooth surfaces are rarly seen and that you must use the overall shape of the broken sample to determine the cleavage (or examine the broken surfaces with a magnifying glass to see the cleavage). Finally each type of cleavage is given an abbreviated name based on the shape of the mineral cleavage fragment (Figure 1); 1 direction of cleavage is called basal cleavage, 2 directions is called prismatic, three directions may be called either cubic or rhombic and 4 directions of cleavage is known as octahedral cleavage.

Types of mineral cleavage fragments and their proper names.

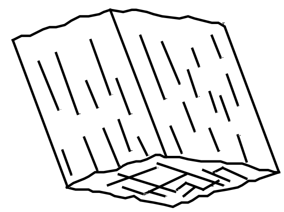
a. Cleavage in one direction
(example: muscovite; **basal** cleavage)



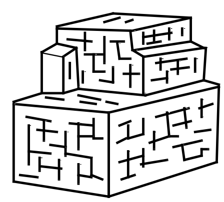
b. Cleavage in two directions at right angles
(example: feldspar; **prismatic** cleavage)



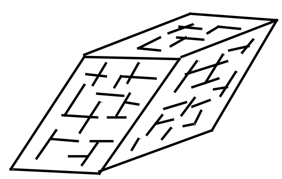
c. Cleavage in two directions not at right angles
(example: hornblende; **prismatic** cleavage)



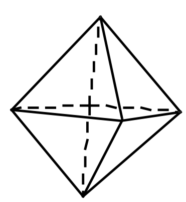
d. Cleavage in three directions at right angles
(example: galena; **cubic** cleavage)



e. Cleavage in three directions not at right angles
(example: calcite; **rhombic** cleavage)

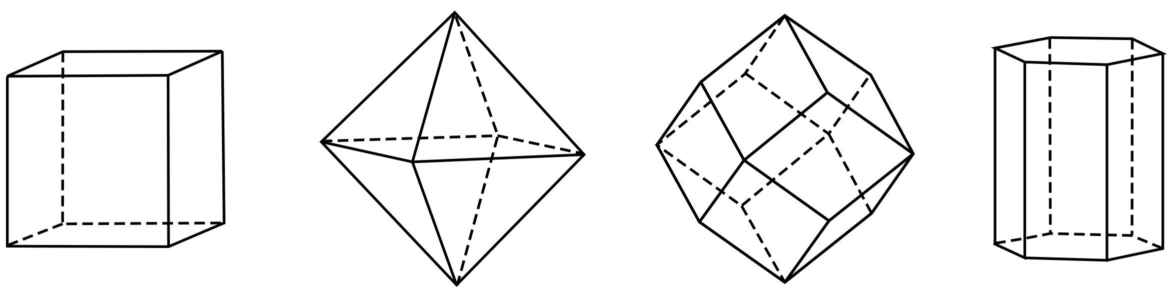


f. Cleavage in four directions
(example: fluorite; **octahedral** cleavage)



Crystal Form

A crystal is a near-perfect geometric shape that is the outward expression of the orderly internal atomic structure of a mineral. All minerals are crystalline, but not all minerals display the outward geometric shape of a crystal. Crystals need time to grow large enough to be visible and room in which to grow in. Without the time or the space, a mineral will have crystals that are too small to be seen without the aid of a microscope. If they are visible, the shape of a crystal, or its crystal form, is an excellent physical property for the recognition of a mineral because every mineral has a particular crystal form. Figure XX shows several possible crystal forms. Be warned that is very common to confuse a mineral crystal for a cleavage fragment. Mineral cleavage is reproducible when a mineral is broken, but if you break the smooth faces of a crystal then you destroy the crystal. The smooth faces of a crystal are not reproducible when the crystal is broken.



Several crystal shapes that can be found in some minerals.

Specific Gravity

Specific Gravity (often abbreviated SG) is the weight of a mineral compared to the weight of an equal volume of water. It is literally how dense or heavy a mineral feels for its size. Minerals that have a low metal content tend to have low specific gravities (3 to 5) and feel very light when held. Minerals with a high metal content tend to have high specific gravities (>5) and may feel very heavy, especially when compared to lower specific gravity samples of equal size.

Color

Color is generally considered a poor criteria for mineral identification. Most minerals, when absolutely pure, are either clear or white. But absolutely pure minerals are a rare find in nature. Many minerals are colored by trace amounts of impurities present in the environment in which they formed. Some relatively common minerals, such as quartz and calcite, may exist in any color. Variations in color of a given mineral is known as mineral varieties. If we take quartz as an example:

COLOR	VARIETY
- clear crystals	Rock Crystal
- purple	Amethyst
- red	Rose Quartz
- white	Milky Quartz
- gray to black	Smoky Quartz
- yellow	Citrine
- green	Adventurine
- fine-grained red	Jasper
- fine-grained white to light gray	Chert
- fine-grained dark gray to black	Flint
- fine-grained banded	Agate
- and so on for about 120 known varieties	

Some minerals are more abundant in particular varieties and so color is a more useful for those particular minerals. The only way to know if the color of a mineral is a useful physical property for identification is to look at as many samples as is possible and to note any color variations and whether one color seems to appear more often than others.

Special Properties

There are numerous physical properties that are useful for recognizing either individual minerals or small groups of minerals. These are known as “special properties” and a few are listed below:

Magnetism - Because of their extremely high metal content (notably cobalt, iron or nickle) a very few of the over 4000 known minerals can stick to a magnet.

Elasticity / Flexibility - Elasticity is the ability for a mineral to snap back when bent, like a rubber band. Flexibility means that it will bend slightly but will not snap back like a rubber band.

Striations - Small parallel lines on the surfaces of some crystals and on some cleavage fragments as a result of the way the mineral formed.

Opacity - Minerals that will let light travel through them and you can see an image through them are known as transparent minerals. Those which will allow light to pass through, but you can not see an image through are called translucent minerals. Those that will not let light to pass through them are called opaque minerals.

Smell - Minerals with a high sulfur content will give off the odor of rotten eges when rubbed. Many clay minerals have a very earthy or clay-like smell when warmed by your breath.

Taste - A small group of minerats known as ‘salts’ have a salty taste (table salt is a mineral ‘salt’).

Feel - Minerals with a Mohs hardness of 1 have either a soapy or greasy feel when rubbed because of their extreme softness.

Identification of Nonsilicate Minerals And Their Uses

Introduction

One of the five parts of the definition of a mineral is that all minerals have a definite chemical composition. Since minerals are the basic building blocks of rocks and rocks are what make up the earth's crust, the chemical composition of minerals reflects that of the earth's crust itself. Below is a table listing the 8 most abundant elements in the earth's crust.

Elemental Composition of the Earth's Crust (by weight).

Oxygen	46.6%
Silicon	27.7%
Aluminum	8.1%
Iron	5.0%
Calcium	3.6%
Sodium	2.8%
Potassium	2.6%
Magnesium	2.1%
All Others	1.4%

From this table it can seen that almost 75% of the earth's crust consists of just two elements; silicon and oxygen. This provides a convenient means of separating the almost 4000 known minerals into two large groups for the purpose of study and identification; the silicate minerals and the nonsilicates minerals. Silicate minerals are those that contain both silicon and oxygen (and can contain other elements as well). Silicate minerals are also known as rock-forming minerals because they make up the vast bulk of the rocks in the crust. Minerals that may contain either silicon or oxygen, but not both, as well as containing other elements are classified as nonsilicate minerals. Although nonsilicate minerals are not as abundant as silicate minerals, they are nonetheless an extremely important group of minerals. Many of these minerals are extracted from rock by miners and processed as ore minerals or minerals that contain high amounts of metals. It is from these minerals that we acquire the world's stockpile of iron, copper, zinc, lead, gold and other metals. Other nonsilicates are mined as industrial minerals and when processed become critical ingredients in the manufacture of such items as concrete, wall board, paper and can even be found in some of our foods, medicines and clothing.

In this lab we will focus on using the fundamental physical properties from Lab 1 to identify a collection of the more common and more important nonsilicate minerals. In addition, we will see how the nonsilicate minerals are classified and groups both by chemical composition and usage.

Chemical Classification and uses of Minerals

Minerals are grouped chemically based on their major cation (a positively charged ion), anion (a negatively charged ion) or complex (generally negatively charged groupings of ions)

Chemical Classification and Common Uses for Selected Nonsilicate Minerals

Chemical Class	Chemical Makeup	Mineral Name	Common Uses
Native Elements	elements found in nature in their nearly pure form	Graphite	lubricant; high temperature crucibles; mixed with clay, the lead in pencils
		Sulfur	battery acid; certain medicines; nylon and rayon cloth; matches; explosives; many others
		Native Copper	important ore mineral of copper
Sulfides	metal + sulfur	Galena	major ore mineral of lead
		Sphalerite	major ore mineral of zinc
		Chalcopyrite	major ore mineral of copper
		Pyrite	a source of sulfur for sulfuric (battery) acid
Oxides	metal + oxygen	Hematite	important ore mineral of iron
		Magnetite	major ore mineral of iron
		Corundum	abrasives, sandpaper; when pure and red calley ruby, other gem varieties called sapphire
Hydroxides	metal + oxygen + hydrogen	Limonite	minor ore mineral of iron
Halides	metal + halogen (chlorine or fluorine)	Halite	salt for food and many industrial uses
		Fluorite	a flux for manufacturing steel and aluminum
Sulfates	metal + sulfur + oxygen	Gypsum	used in wallboard, plaster and concrete manufacturing
Carbonates	metal + carbon + oxygen	Calcite	major ingredient in cement; many other uses
Phosphates	metal + phosphorus + oxygen	Apatite	fertilizers; detergents; explosives
Silicates	silicon + oxygen or metal + silicon + oxygen	see Lab 3 for list	Major Rock Forming Minerals

Identification of Nonsilicate Minerals

Mineral identification involves the systematic use of physical properties to separate a single pile of minerals into smaller and smaller piles until you zero in on the correct name. This generally involves the use of a mineral key (see the following page). The following steps should enable you to identify all of the minerals in this lab.

1. *Determine the Luster.* Minerals with a dark-colored streak have a metallic luster and the streak color is a very important physical property for identification of a particular metallic mineral. Minerals with a light or white streak have a nonmetallic luster and streak color is NOT a good property for identifying these minerals.

2. *Determine the approximate Hardness*. The key is using the terms soft, medium and hard by the following criteria:

Can scratch with a fingernail	$H \leq 2.5$	Hardness is **Soft**
between a fingernail and a steel nail	$H > 2.5 \leq 5$	Hardness is **Medium**
can scratch a steel nail	$H > 5$	Hardness is **Hard**

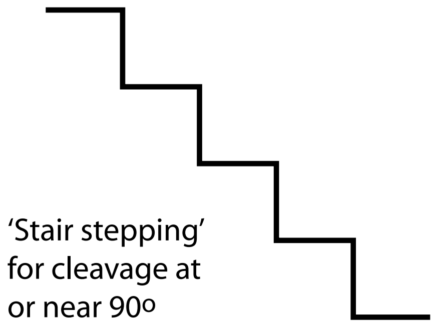
Other common tools may be used (see the table in Lab 1) and the Mohs Hardness Set is available if you wish is get a more exact hardness. Five important things to keep in mind when testing the hardness of an unknown mineral:

- minerals with the same hardness will scratch each other
- the hardness of any ‘Mohs Mineral’ in you set of unknowns is its major physical property;
- scratch each sample with the other and wipe off any powder so that you can see the scratch;
- the harder the mineral is, the harder it is to scratch that mineral;
- NEVER use your jewlery for hardness testing !! There is a vast difference between hardness and brittleness in a mineral. Harder minerals (your jewelry) will tend to be brittle and shatter easily.

3. *Check for Cleavage or Fracture*. Minerals with ‘good ‘cleavage should show that cleavage readily. In fact, if a mineral has good cleavage and is transparent to translucent, you can usually hold the mineral up to a light and see fine parallel traces of that cleavage within the mineral. If a mineral has fair to poor cleavage first look at the overall shape of the mineral:

- in basal cleavage the minerals tend to be flat if broken
- in prismatic cleavage the minerals then to look like bricks with rough ends
- in cubic or rhombic cleavage you should see either square box shapes or bent box shapes
- in octahedral cleavage you can see triangle shapes on freshly cleaved surfaces.

A hand lens is also a handy tool for checking cleavage. Any cleavage at 90^o will show regular stair steps on broken edges. Any cleavage not at 90^o will show irregular stair steps on broken edges (see diagram on the next page).



Samples with an irregular fracture often appear grainy-looking or have sharp, ragged edges like broken metal. Shaples with a conchoidal fracture have very sharp, rounded breaks like pieces of broken bottle glass.

4. *Check the 'Other Properties'*. There may be special properties for a given unknown mineral or the color or Specific Gravity (abbreviated SG in the mineral key) may give clues to its identification.

L.	Streak	H.	Cleavage / Fracture	Other Properties	Name
Metallic Luster	black to lead gray	Soft	basal (fair)	H = 1; SG = 2.1; greasy to the touch, marks on paper	**Graphite**
	lead gray		cubic (good)	H = 2.5; SG = 7.5; feels very heavy; bright metallic silver colored	**Galena**
	reddish-brown	Soft to Med	irregular fracture	H = 1 - 5; SG = 5 - 6; reddish-brown color common	**Hematite**
	yellow - brown		irregular fracture	H = 1 - 5; SG = 4; yellow-brown color common	**Limonite**
	bright copper red	Med	irregular fracture	H = 3; SG = 4.2; metallic copper color with common light green tarnish	**Native Copper**
	light brown		6 directions of cleavage appears to have an irregular fracture	H = 3.5 - 4; SG = 4; resinous brown to nearly black in color; strong sulfur odor when rubbed	**Sphalerite**
	black with green tint		irregular fracture	H = 3.5 - 4; SG = 4; brass-yellow, often tarnished to bronze, purple or black	**Chalcopyrite**
	black	Hard	irregular fracture	H = 6; SG = 5.2; black color, granular appearance; will stick to a magnet	**Magnetite**
	black		irregular fracture	H = 6; SG = 5; shiny brass-yellow color; often in cubic crystals with striations on the crystal faces	**Pyrite**
Nonmetallic Luster	NOT USEFUL FOR THESE MINERALS	Soft	irregular fracture	H = 2; SG = 2.1; yellow to yellow-brown color; strong sulfur smell when rubbed	**Sulfur**
			basal (good), plus 2 other fair cleavages	H = 2; SG = 2.3; clear when pure; thin edges slightly flexible	**Gypsum**
			cubic (good)	H = 2.5; SG = 2.2; clear when pure; soluble in water; salty taste	**Halite**
		Med	rhomb (good)	H = 3; SG = 2.7; clear when pure, may be white or any color depending on impurities	**Calcite**
			octahedral (good)	H = 4; SG = 3.3; clear when pure, common colors include light green, yellow and purple	**Fluorite**
			irregular fracture	H = 5; SG = 3.2; commonly green or brownish in color; 6-sided crystals common, but brittle and breaks easily	**Apatite**
		Hard	irregular fracture	H = 9; SG = 4; commonly brown or gray in color, but may be red or blue; 6-sided crystals very common	**Corundum**

NONSILICATE MINERAL FORM

Mineral Name	Two Characteristic Physical Properties

Questions

1. Of the minerals that display a metallic luster, list 3 that appear ‘shiny’ like metal.

2. Of the minerals that display a metallic luster, list 3 that appear ‘dull’ like metal rust or tarnish.

3. What is the streak color of most of the nonmetallic minerals ?

4. Why is streak a poor physical property to use for nonmetallic minerals ?

5. Hematite, limonite and magnetite are all iron rusts. How can you use streak to distinguish between these 3 minerals ?

6. The origin of the mineral name chalcopyrite literally means ‘copper plus pyrite’. Does this make sense given the color of these 2 minerals ? Explain in detail.

7. Sphalerite is a chemical compound consisting of zinc and sulfur. How can you detect the high sulfur content in this mineral (you might want to study the native sulfur sample carefully)?

8. A cleavage fragment is a mineral bounded on all sides by its cleavage planes. Describe the difference between the halite and calcite cleavage fragments.

9. Which nonmetallic mineral lacks a streak and why ?

10. Most of the apatite samples are partually fractures crystals. How can you determine this?

11. What would be a single, simple test to tell the difference between gypsum, calcite, fluorite and apatite ?

12. Minerals that are about to part along their cleavage planes often display ‘cleavage traces’ in the direction they are about to cleave in. How can you use cleavage traces to detect fluorite’s octahedral cleavage ?

13. Which 2 of your minerals are actually native (pure) elements ?

14. Students often mistake the crystal of corundum for a mineral with cleavage. What observation can you make to prove that the corundum samples are, in fact, crystals ? (Hint, think about the definition of cleavage and your answer to question #10.)

15. Compare the luster of pyrite and halite. Why is the term ‘shiny’ a poor term to use as a physical property to describe both of these minerals ?