ES 104: Laboratory # 6
PHYSICAL PROPERTIES OF MINERALS AND MINERAL IDENTIFICATION

Introduction

Minerals are naturally occurring, usually inorganic, solids that possess a definite chemical composition and a specific, orderly arrangement of atoms. This lab will help you to develop the ability to identify common minerals found at Earth's surface. Although there are literally thousands of minerals, the small number of the most common rock forming, ore, and industrial minerals studied here constitute a large part of Earth's crust. Identification is accomplished by testing and observing the physical properties studied in the first of part of this laboratory. The second part of the lab will focus on describing the physical properties of a mineral and on identifying minerals using the physical properties.

Objectives

- Recognize and describe the physical properties of minerals
- Develop and use a mineral identification key to name minerals
- Identify minerals using physical properties

Useful Websites

- http://mineral.galleries.com/minerals/property/physical.htm
- http://www.rockhounds.com/rockshop/xtal/part2.html
- http://geology.csupomona.edu/alert/mineral/shape.htm
- http://mineral.galleries.com/minerals/cleavage.htm
- http://webmineral.com/help/Luster.shtml

Name_____**KEY**_________________________

Lab day ______Lab Time_____________________

Pre-lab Questions – Complete these questions before coming to lab. (Note: This Pre Lab is not **two** pages.)

Briefly define the following key words.

1. Element Pure substance containing atoms that all have the same number of protons	2. Hardness Resistance to abrasion
3. Mineral Naturally occurring inorganic crystalline solid with a unique chemical composition	4. Cleavage Tendency of mineral to break along weak bonding planes
5. Color Obvious feature of a mineral, although often not a good diagnostic feature	6. Density Mass per unit volume—the 'heft' of a specimen
7. Streak Color of a powdered sample of a mineral	8. Fracture Breakage surface of a mineral that is not cleavage: conchoidal fracture is diagnostic for some minerals
9. Luster Quality of reflected light from mineral surface: metallic or glassy, or dull	10. Crystal form Natural growth surfaces of mineral determined by arrangement of atoms at surface
11. Magnetism Attraction of mineral specimen to a magnet. Natural property of a mineral to attract iron	12. Effervescence Release of gas from liquid, bubbling appearance. Carbonate minerals release CO_2 gas in HCl.

1. How is density calculated? (Show formula with units.)

Measure mass with balance. Measure volume by displacement.
Calculate mass (grams)/volume (cm^3)
cm^3 = mL

2. What is the difference between a silicate and non-silicate mineral? Include some examples of each type of mineral.

Silicate minerals contain silicon and oxygen. Feldspar is the most common silicate. If a mineral does not have both silicon and oxygen, it is a non-silicate: halite, calcite, galena, pyrite, gypsum, hematite, magnetite are non-silicates included in this lab exercise.

Part A: Activities Focusing on Physical Properties

Minerals exhibit certain diagnostic properties, called physical properties, which can be tested and observed, thereby leading to the correct identification of the mineral. Many (but not all) of these properties are unique to a given mineral. One of the keys to identifying minerals is observing a combination of physical properties displayed by a mineral. You must be sure of the meaning of each of the physical properties. On the following pages, you will study these properties: luster, color, streak, heft, density, hardness, cleavage, fracture, crystal form, magnetism, and effervescence in dilute, cold hydrochloric acid (HCl).

STATION #1: Luster and Color

1. Study the various mineral specimens provided. How many specimens can be grouped into each of the following luster types?

___**2**______ Metallic ____**2**_____ Nonmetallic-glassy

Describe Luster in your own words.

The overall reflective property of a mineral: does it look like metal? Then it is metallic. If it does not look like metal, is it shiny or dull?

2. Study the mineral specimens of quartz (Sample #3) provided. What is the reason for the variety of colors that quartz exhibits? (**HINT**: Think about what a single drop of food coloring does to a glass of water.)

Trace amounts of impurities can impart color

3. Is color a reliable physical property to help identify a given mineral specimen? Keep in mind your investigation in question 2 above. Explain your answer.

Quartz comes in a variety of colors. It is not a reliable property to use to identify it. However, pyrite, turquoise, malachite have diagnostic colors.

STATION #2: Other Physical Properties: Streak, Magnetism, and Effervescence

1. Describe in your own words:

   Streak—

   Color of powdered form of mineral

   Magnetism—

   Attraction to a magnet, property of iron

   Effervescence—

   Fizzing, release of gas bubbles.

2. Examine the collection of samples provided and complete the data table by recording the following observations for each sample:

Sample Number	**Streak**	**Magnetism**	**Reaction to HCl**
#1	**Red**	**Not**	**None**
#2	**Black**	**Has magnetism**	**None**
#13	**Clear**	**Not**	**Effervesces**

STATION #3: Cleavage, Fracture, and Crystal Form

Study the collection of samples of single mineral crystals. The samples are separated into smaller groups: several samples exhibiting cleavage (Samples #5, #6, and #13), a sample showing fracture (Sample #3), and a sample demonstrating crystal form (Sample #4).

Cleavage and **Fracture** are related to how a mineral breaks apart. They are controlled by the internal atomic arrangement of the mineral.

1. Between cleavage ~~and~~ **or** fracture, which is controlled by planes of weak chemical bonding?

CLEAVAGE

2. Briefly explain in relation to crystal structure of the atoms.

CRYSTAL STRUCTURE IS THE INTERNAL ARRANGEMENT OF ATOMS. SOME OF THE BONDS ARE WEAKER, AND THE MINERAL WILL BREAK ALONG THESE PLANES

Crystal Form is also controlled by the internal atomic structure but is not related to how a mineral breaks.

3. What is Crystal Form?

THE INTERNAL ARRANGEMENT OF ATOMS IS EXPRESSED ON THE EXTERNAL MINERAL-GROWTH SURFACES.

Study the group of minerals exhibiting cleavage and complete the data table. For each, describe the cleavage in terms of the number of directions and the angle between them. Also, provide a simple sketch of the sample emphasizing the cleavage.

Sample Number	# of Directions	Angle (90° or not	Sketch
#3	NONE		
#5	1		
#6	3	90°	
#13	3	NOT 90°	

STATION #4: Density

The density of a mineral can be estimated by hefting the mineral in your hand. Some **minerals will feel heavier** than others for a given sample volume. This is a **subjective** determination. For mineral identification, it is **better to measure** the mineral sample's mass and volume and calculate the density. Density can be calculated with a high degree of accuracy (although your measurement may not seem so because you are using a relatively primitive method). The density of any substance is the mass per volume, shown by the equation:

Density = Mass/Volume.

Perhaps of greater importance, any person doing the determination should get the same answer: the answer is objective and not subjective. The concept that anyone doing the experiment should get the same answer is fundamental to science.

Step 1: Find the mass of your specimen using the balance.

Step 2: Determine the volume of the specimen by displacement of water in a graduated cylinder.

Step 3: Use the equation to determine the value of the density.

Specimen number	1) Mass of specimen	2)Volume of specimen	3) Density of specimen	*Show work here (include units):*
clear			**g/cm^3** **2.65 g/cm^3**	**if you are in these ballparks, you are ok**
gold **red**			**5.02 g/cm^3** **5.26 g/cm^3**	**if you get more than 8, or less than 1, you did it wrong**
UNITS!!	**Grams**	**Milliliters=cm^3**	**Grams/cm^3**	

1. What volume of quartz (density = 2.65 g/cm3) would weigh 1 gram? __**0.377 cm³**________

Show work here (include units):

$$\frac{1g}{2.65g/cm^3} = 0.377cm^3$$

or use proportion: $$\frac{1g}{?\,cm^3} = \frac{2.65g}{1cm^3}$$

A term quite similar to density that is often used is specific gravity (S.G.). Specific gravity.is a unitless comparison of a mineral's density to the density of water. Specific gravity can be thought of as the number of times the mineral is heavier than that volume of water. For example, if a mineral has a specific gravity of 3.47, it is 3.47 times heavier than if that same specimen were made of water. Water has a specific gravity of 1.

1. If a substance had a specific gravity of 2.54, would it float or sink in water? ___**sink**_______
2. Is the specific gravity of ice greater or less than 1?_ ___________________**less**___________
3. Is the specific gravity of oil greater or less than 1? ___**less**

STATION #5: **Hardness**

The following hardness guide is useful to bracket the hardness of an unknown sample.

Hardness Guide:

Hardness	**‘Code’**	**Description**
less than 2.5	<2.5	Mineral can be scratched by fingernail (H = 2.5).
2.5 to 3.5	2.5-3.5	Mineral cannot be scratched by fingernail (H = 2.5) and mineral cannot scratch penny (H = 3.5).
3.5 to 5.5	3.5-5.5	Mineral can scratch penny (H = 3.5) and cannot scratch glass (H = 5.5).
greater than 5.5	>5.5	Mineral can scratch glass (H = 5.5).

Determine the hardness for the small group of minerals provided and complete the data table.

Sample	**Hardness (use code from table above)**
#3	**>5.5**
#7	**>5.5**
#13	**2.5-3.5**
#14	**<2.5**

Part B: Activities focusing on Mineral Description and Mineral Identification

Description

You are now ready to collect a complete set of data of the physical properties useful in mineral identification. Determine the physical properties of each sample and record your observations in the data table provided on the following page. Complete the collection of mineral properties before continuing on to identify the minerals by name.

Identification

Mineral identification is a process of elimination based on determinations of physical properties. In this activity, you will use an identification key for the minerals that you described above. To use a key to identify minerals, you will be given a series of choices about the properties of a mineral. For most of the identification process, the choices will be “either this or that”. Compare your determinations of mineral properties with the mineral identification tables in the following pages.

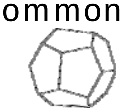
To identify the fifteen ‘unknown’ minerals, follow the divisions of the key tables: first choose the proper table by the luster of the mineral. Notice Table 2a is for identifying those minerals that have a metallic luster. Table 2b and 2c are for minerals that do not have metallic luster: Table 2b is for minerals that are light-colored, and 2c is for minerals that are dark colored. Each table for luster is divided into two sections: softer than glass, and harder than glass. These sections are further divided by the absence or presence of cleavage, and the characteristics of the cleavage if it is present.

After you have identified the minerals, you should concentrate on a small number (1-3) of properties for each mineral to help you remember how to identify it. These are considered “diagnostic properties” for that mineral. A particular mineral will have a set of properties that are diagnostic for it. Some properties that are diagnostic for certain minerals are of no significance for other minerals. This is especially true for color, or some special properties like magnetism or effervescence in hydrochloric acid.

Mineral Description Table

Sample #	**Luster** Metallic/ glassy/dull	**Hardness** Range code pg. 6-9	**Cleavage /** # of dir + angle of intersection. **+ / - crystal form**	**Streak** color	**Color / Other properties** (if present)	**MINERAL NAME**
1	Submetallic	>5.5	None	Red	Gray	Hematite
2	Submetallic	>5.5	None	Black	Dark gray, magnetic	Magnetite
3	Glassy	>5.5	None	None	Gray	Quartz
4	Metallic	>5.5	No cleavage, soccer-ball form	Black	Yellow	Pyrite
5	Glassy	<2.5	1 direction, perfect	Brown	Brown	Biotite
6	Glassy	2.5-3.5	3 directions, perfect, 90^{o}	Clear	White	Halite
7	Glassy	>5.5	2 directions, excellent, not 90^{o}	None	Black	Hornblende (amphibole)
8	Glassy	>5.5	2 directions, excel., 90^{o}	None	Gray,white Striations	Plagioclase feldspar
9	Glassy/dull	>5.5	None	None	Green	Olivine
10	Glassy	>5.5	2 directions, excel., 90^{o}	None	Salmon pink	Orthoclase feldspar
11	Glassy	>5.5	2 directions, good, 90^{o}	None	Dark green	Augite (pyroxene)
12	Metallic	3.5-5.5	3 directions, perfect, 90^{o}	Gray	Gray	Galena
13	Glassy	2.5-3.5	3 directions, excel., not 90^{o}	Clear	White, fizzes	Calcite
14	Glassy	<2.5	1 direction, perfect	Clear	White	Gypsum
15	Glassy	<2.5	1 direction, perfect	Clear	Light gray	Muscovite

Table 2a: Mineral Identification Key—Metallic Luster

Hardness	Cleavage	Diagnostic Physical Properties	Mineral Name
Harder than glass	Absent	Brass yellow color, tarnishes brown to green; **greenish or brownish black streak**; cubic or pyritohedron crystals common;  **H = 6 – 6.5**, SG=5.0	**Pyrite** FeS_2
		Pale brass yellow to whitish gold color; dark gray streak; radiating masses and "cockscombs:" common; H = 6 – 6.5, SG=4.9	**Marcasite**[1] FeS_2
		Dark gray to black color, dark grey to black streak; **magnetic**; massive or "grainy"; may have 'submetallic' luster; H = 6, SG=5.2	**Magnetite** Fe_3O_4
		Silver to gray to red-brown color, **red-brown streak**; often composed of glittery flakes; H=5-6.5, SG~5	**Hematite** Fe_2O_3
		Grayish or dark brown to yellow-brown color; **yellow-brown streak**; H = 5 – 5.5, SG=4.4	**Limonite**[*] $Fe_2O_3\ nH_2O$
Softer than glass	Present	Silver gray color, **gray streak**; **cubic cleavage** (three directions at 90^o), but may be distorted; H = 2.5 (cannot be scratched by fingernail); **S.G. = 7.4 – 7.6**	**Galena** PbS
	Absent	Golden yellow color, **tarnishes to purple**; Greenish black to dark gray streak; H = 3.5 – 4, SG=4.2	**Chalcopyrite**[*] $CuFeS_2$
		Copper to dark brown color, **tarnishes to green**; copper streak; H = 2.5 3; S.G. = 8.8–8.9	**Copper**[*] Cu
		Dark gray color; dark gray streaks; **marks paper easily**; greasy feel; H = 1; S.G. = 2.1-2.3	**Graphite**[*] C

[1] These minerals are not included with ES 104 lab specimens.

Table 2b: Mineral Identification Key— Nonmetallic Luster, Light Colored

Hard-ness	Cleav-age	Diagnostic Physical Properties	Mineral Name
Harder than glass	Present	White to pink color; **two directions of cleavage at 90°; H=6**, SG=2.55; subparallel banding (exsolution lamellae) may be present on cleavage faces	**Potassium Feldspar** [2] (Orthoclase) $KAlSi_3O_4$
		White to blue-gray color; **two directions of cleavage at nearly 90°; H=6**, SG=2.65; may have striations (parallel grooves) on cleavage faces	**Plagioclase Feldspar**† $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
	Absent	White, gray, or pink color; usually massive; may have hexagonal prism with pyramid crystals; transparent to translucent; glassy luster; conchoidal fracture; **H=7**, SG=2.65	**Quartz** † SiO_2
		Olive green to yellow-**green color**; granular masses; grains glassy with conchoidal fracture; H=7: reduced by alteration, SG=3.3-4.4	**Olivine** † $(Fe,Mg)SiO_4$
Softer than glass	Present	Colorless, yellow, blue, green, or purple; four directions of cleavage **(octahedral)**; transparent to translucent; **H=4**, SG=3.2	**Fluorite*** CaF_2
		White, gray, or pink color; three directions of cleavage not at 90° (rhombohedral); fizzes in dilute HCl if powdered; H=3.5–4, SG=2.85	**Dolomite*** $CaMg(CO_3)_2$
		Colorless, white, yellow, or gray; rhombohedral cleavage (**three directions, not at 90°**); **fizzes** in dilute HCl; H = 3, SG=2.72	**Calcite** $CaCO_3$
		Colorless, white or gray; **cubic cleavage** (three directions at 90°); salty taste; dissolves in water; **H = 2.5**, SG=2.1-2.3	**Halite** NaCl
		Colorless, clear brownish or yellowish color; one direction of cleavage; usually **thin, elastic, transparent to translucent sheets;** H=2.5, SG=2.8	**Muscovite**(mica)† $KAl_2(AlSi_3O_{10})(OH)_2$
		Colorless to white; massive, or one good direction of cleavage (and two poor) forming thick; nonelastic, translucent sheets; **H = 2**, SG=2.3	**Gypsum** $CaSO_4\ 2H_2O$
	Ab-sent	White earthy masses resembling chalk; plastic and sticky when wet; H=1–1.5, SG=2.6	**Kaolinite*** $Al_4Si_4O_{10}(OH)_8$

*These minerals are not included with ES 104 lab specimens.

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[2] Minerals important to formation of igneous rocks: study these carefully because they will be used to help identify igneous rocks in the next two labs.

Table 2c: Mineral ID Key—Nonmetallic Luster, Dark Colored

Hard-ness	Cleav-age	Diagnostic Physical Properties	Mineral Name
Harder than glass	Present	Dark gray to blue-gray color; two directions of **cleavage at ~90°; H = 6**, SG=2.62-2.76; striations (parallel grooves) may be present on cleavage faces	**Plagioclase Feldspar**† $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
		Black to dark green color; two directions of cleavage intersecting at 87° and 93°; often massive in appearance; **H = 5.5**, SG=3.1-3.5	**Augite** (Pyroxene)† Ca, Mg, Fe, Al Silicate
		Black to dark green color; two directions of **cleavage intersecting at 60° and 120°**; often massive or splintery in appearance; H=5.5, SG= 3.0-3.3	**Hornblende**† (Amphibole) Na, Ca, Mg, Fe, Al Silicate
	Absent	Dark gray to smoky brown color; usually massive; transparent to translucent; glassy luster; **conchoidal fracture; H = 7**. SG=2.65	**Quartz**† SiO_2
		Black to dark green or olive green color; granular masses; single grains are glassy with conchoidal fracture; H = 7, SG=3.27-4.37	**Olivine**† $(Fe,Mg)SiO_2$
		Dark red to brownish-red color; translucent; often has smooth, parallel fractures resembling cleavage; **H = 7**, SG=3.5-4.3	**Garnet*** Fe, Mg, Ca, Al Silicate
		Dark gray to black color, dark grey to black streak; **magnetic**; massive or "grainy"; may have 'submetallic' luster; H = 6, SG=5.2	**Magnetite** Fe_3O_4
		Grayish to dark brown to yellow-brown color; **yellow-brown streak**; amorphous; opaque, earthy appearance ; H = 1.5–5.5, SG=4.37	**Limonite*** $Fe_2O_3\ nH_2O$
Softer than glass	Present	**Dark brown to dark green color**; one direction of cleavage; usually in **thin, elastic, transparent to translucent sheets; H = 2.5–3**, SG=2.95-3.0	**Biotite** (Mica)† $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
		Dark green to green color; one direction of cleavage; usually in thin, opaque, curved sheets; often massive with greasy feel; H=2.5, SG=2.6-2.9	**Chlorite*** Mg, Fe, Al Hydrous silicate
	Absent	Dull red color; **reddish-brown streak**; opaque, earthy appearance; H=1.5–5.5, SG=5.2	**Hematite** Fe_2O_3
		Grayish or dark brown to yellow-brown color; **yellow-brown streak**; amorphous; opaque, earthy appearance; H = 1.5 – 5.5, SG=4.37	**Limonite** $Fe_2O_3\ nH_2O$

* These minerals are not included with ES 104 lab specimens.
† Minerals important to formation of igneous rocks

*For your information...***Mineral uses and some mineral facts:**

Barite	principle source of barium and sulfate for chemical industry; used in petroleum industry as drilling mud
Calcite	used for manufacture of cement and lime for mortars, used as soil conditioner, used as flux for smelting metallic ores, building industry
Chalcopyrite	important ore of copper; oxidized surfaces show iridescence.
Feldspars	used in manufacture of porcelain; source of aluminum in glass industry
Fluorite	flux in making steel; used in chemical industry for hydrochloric acid; high-grade ore is used in making optical equipment
Galena	most important ore of lead; lead is used in batteries, in metal products as an alloy, in glass making; used to be the principal ingredient in paints. The Romans used lead for indoor plumbing, which may have resulted in lead poisoning of the higher, classes and contributed to the downfall of the Roman Empire.
Garnet	semi-precious gemstone, used in abrasive products (sand paper)
Graphite	this is the "lead" of pencils, also used in protective paints in foundries, batteries, and electrodes; in fine powder form, it is used as a lubricant
Gypsum	plaster (wall board, sheet rock); used in Portland cement; soil conditioner for fertilizer
Halite	table salt; source of Na and Cl for the chemical industry
Hematite	most important ore for steel making; used in pigments, some use as gemstone
Kaolinite	used for brick, paving brick, drain tile, ceramic products, and as filler in glossy paper
Magnetite	minor ore of iron
Olivine	some used as gem (peridot); used in casting industry because of refractory properties (means high melting temperature)
Quartz	some use as gemstone; in sand form, used in mortar, concrete, as flux, and for abrasive products. Artificial quartz is now used in radios and for optical instruments (quartz permits both the transmission and reception on a fixed frequency).
Sphalerite	most important ore of zinc; galvanized metals are covered with zinc to prevent rusting.
Talc	used in manufacture of paint, paper, roofing materials, rubber, cosmetic powders, and talcum powder; used as insulators in electrical industry

Name_______**KEY**________________________

Lab day ______Lab Time_____________________

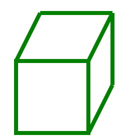
Post-Lab Questions

1. Describe the procedure for identifying a mineral and arriving at its name.

Determine Luster, hardness, if it has cleavage, and the angle between directions of cleavage if there is more than one direction. Then use the determinative tables to narrow the choices, and read the specific information to help decide which mineral it is.

2. Name the physical property that is described by each of the following statements:
   a. Breaks along smooth planes: **Cleavage**_________________
   b. Scratches glass: **Hardness greater than 5.5**________
   c. A red-colored powder on unglazed porcelain: **Streak is red**__
3. Describe the shape and sketch a mineral that has three directions of cleavage that intersect at 90°.

The mineral will break into small rectangularor cubic shapes



4. How many directions of cleavage do the feldspar minerals (potassium feldspar and plagioclase) have? _

_two directions, at 90^{o} to one another________

5. How would you tell the difference between a crystal face and a cleavage plane? **Cleavage is repeated at breaks, so breaking a sample could help, but looking for parallel planes from one surface to another can be done also. There are only a few distinctive and common crystal shapes (quartz columns, pyrite balls, salt cubes), so if it isn't one of those, it may be more likely to be cleavage.**
6. Which would tell you more about a mineral's identity: luster or hardness? Why?

Hardness can be affected by chemical weathering, so it might not always be as hard as it is defined in tables. Luster can also be affected by weathering, and varies depending on the habit of the mineral (massive crystals, microscopic crystals, etc.). So just defend your point of view. Recall that the determinative tables are arranged by luster first, then hardness, before all other properties, so both are very important.