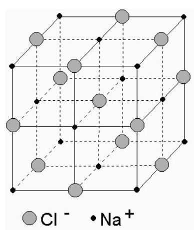
Chapter 1 MINERALS

SECTION I: INTRODUCTION

From the perspective of a gemologist a mineral is an exciting thing! Most gems are minerals and minerals even in their natural form can be quite beautiful and valuable. But what is a mineral, and how do we distinguish it from other substances?

A simple definition of a mineral is that **it is a naturally occurring inorganic** (never living) **solid with a definite internal arrangement of atoms** (crystal structure) **and a chemical formula that only varies over a limited range that does not alter the crystal structure.**

In our world there are many crystalline substances; sugar forms crystals and is formed by organic processes such a photosynthesis. Salt (NaCl, sodium chloride) or as geologists call it, halite, is usually precipitated from evaporating water without organic processes and is thus a mineral.



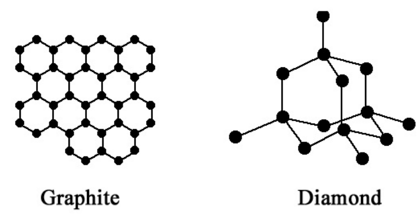


Figure 1. Shown above are the crystal structure (magnified and expanded) of the minerals, Halite (NaCl) and of two carbon minerals, graphite and diamond. The lined between atoms represent chemical bond. The structure of minerals and their bonding make a lot of the difference in the minerals' properties, for example hardness.

Very few things that are solid are not crystalline. However, because in our world much of what we see is formed by life processes, most observed solids are not minerals. You will quickly argue that rocks are all around us and that they are made of minerals, however in terms of variety only about a dozen minerals (the rock forming minerals) are abundant and in fact there is a great deal more variety of organic solids around us than minerals. We rarely spend much time observing minerals and really the average beginning student knows almost nothing about them and their properties. There are around 4,000 known species of minerals and most of them are extremely rare.

Of the few inorganic, non-crystalline solids dealt with in gemology, glass is the most important. Glass forms by rapid cooling of substances that have been melted to a liquid. There are natural and man-made glasses. Man made glass is often used as a **gem substitute or simulant** and should be suspected at all times. Figure 2 on the next page shows an organized mineral structure with an ordered arrangement of atoms and a disorganized substance without a crystal structure. Both can be solid, but a disorganized solid is called non-crystalline or amorphous.

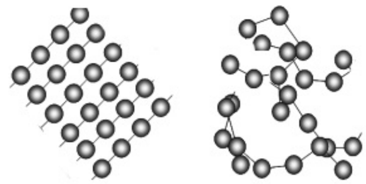


Figure 2. Crystalline and amorphous solids. Both are held by chemical bonds, but crystalline solids have an ordered structure that fills space in 3 dimensions. You can predict where the next atom can be found in the structure.

As with glass, resins and plastics of organic origin, such as natural amber and man-made epoxy and acrylic, also lack crystalline properties and should also be watched for in jewelry. They are usually low density and have much lower melting points than most glasses. However, many organic substances, such as sugars have a crystalline structure.

Rarity is one of the qualities that a gem must posses. A rock forming mineral shares many attributes with a gem, but rarity is not one of them. However, the rock forming minerals often are the reason for gems' rarity because they "dilute" the gems and enclose them; because of the rock forming minerals abundance, it is hard to find gems. Some rock forming minerals can reach gem quality, if they have the required properties of a gem. Normally the mineral quartz is not a gem, but there are varieties that are gems, mainly because of their beautiful color and clarity.

A gem must have at least 3 properties, 1) Beauty, 2) Durability, and 3) Rarity. Many beautiful minerals are collector specimens because of their pleasant shape (usually a crystal form), color, and size. Collectable minerals overlap with the field of gemology, but are not synonymous. When it comes to rarity, consider a gravel or large quantity of rock that has only 1 gram of diamond per 10 million grams of other minerals. This quantity of gems per volume of rock is still economic and explains the cost of gemstones based on rarity. Beautiful crystal may also be rare, but not necessarily gems and thus have value for another reason.

To find these valuable gems, their unique properties must be recognized and exploited. The basic minerals should be recognized and understood so that their context to the gem minerals can be interpreted. Finding a gem mineral requires looking in the right place, and finding the right type of rocks requires recognizing the rock forming minerals and thus identifying rocks.

SECTION II: IDENTIFYING ROCK FORMING MINERALS

PURPOSE

In this exercise we will examine common rock forming minerals and attempt to identify some unknown minerals by testing them. We will study some of their **physical properties** and learn simple tests that can be applied to distinguish minerals. Some of these test have value when testing gem substances in their **rough form**, but few of these test should be applied to cut gemstones.

WHAT WE WILL DO IN THIS LAB

We will do simple tests, but even these can be done with considerable precision if practiced.

Since minerals are the building blocks of most rocks, what we learn today, will be applied to recognizing rocks and gem materials in future laboratories.

1) identification of unknown minerals fragments in trays based on physical properties (1 hr.)
2) identify crystal shapes on ideal specimens (10 minutes; done with your group)
3) relate shape to the crystalline structure of minerals (10 mins.; done with your group)
4) observe crystal structures of the 7 crystal systems using models and natural crystals (10 mins.)
5) look at X-rays of minerals (slide show, 10 minutes)
6) observe some noncrystalline solids (10 minutes; done with your group)

METHODOLOGY and PROCEDURES

A systematic (logically ordered) testing of unknowns and reference to mineral identification tables will allow us to make educated guesses as to the identity of the unknowns in project 1 (identification of mineral fragments). For these exemplar minerals, extreme quantitative (numerical) precision will not be necessary, but careful recording of results and observations are essential.

The student should become familiar with the tests described below (see *Review Questions and terminology* at the end of the chapter). The order in which the tests are done should be based on the data tables used (see next section). Not all tests are necessary or need be applied.

The goal of the tests is to get enough characteristic results to slowly **separate a large pile of minerals** into smaller and **smaller piles**, and ultimately **individual identified samples**. Of course, this may take several steps.

The instructor will give you a list of numbers corresponding to the labeled minerals in our trays of mineral fragments you will test from your trays. Most of these are broken pieces not crystals.

Write the list of mineral numbers here:

1) Luster– Luster is the effect created by light reflecting from the mineral's surface. The most important types are 1) *metallic luster* and 2) *non-metallic luster*. *Dull* and *earthy luster* is often grouped with metallic luster, which will do today. Though these two groupings are enough for common minerals. More specific types of luster terminology important to gemstones include: Adamantine (like a diamond), Chatoyant (such as cat's eye), Greasy, Pearly, Silky, Resinous (like amber or polyurethane), Vitreous (looking like glass, a good example is clear quartz), and Waxy. Gemstone luster will be carefully examined in a later laboratory, but demonstration examples will be displayed in room today.

Step 1 Separating minerals by luster

You have been given a box of minerals. Separate them into the groups Metallic, Earthy or Dull, and Nonmetalic. Record the mineral numbers in the boxes below.

Metallic	Earthy or Dull	Nonmetalic

Demonstrations of Special Lusters

Special Characters Related to Luster are demonstrated at the front or side of the room. Familiarize yourselves with–**Chatoyancy** is the character of having a fibrous texture as seen in tiger's eye. Tiger's eye has fibers embedded in quartz and has a strong chatoyancy, but other minerals such as tourmaline and cat's eye chrysoberyl also show this. **Schiller** is best seen in labradorite feldspar that varies in color as the mineral is moved and looks like the wings of some iridescent butterflies. Labradorite makes an attractive building material and semiprecious stone. Schiller is also seen in some gems such as moonstone. Pearly luster as seen in the mineral ulexite(sometimes called the TV stone). Greasy luster as in some chalecedony, a type of microcrystalline(also called cryptocrystalline) quartz. Glassy luster as seen in broken glass, and resinous luster as seen in amber (a fossilized tree resin; not a mineral)

Put the correct numbers and your assumed names for the samples base on their luster.

Chatoyancy	Schiller	Pearly	Greasy	Glassy	Resinous

2) Color– Color is how a mineral looks in reflected light. If the mineral is transparent this too can be noted. See what color most closely matches those used in the descriptions of minerals, but also note that there may be considerable variation. For instance, quartz occurs in many colors such as colorless, milky, rose, smokey, purple (amethyst), and yellow (citrine) and also varies from transparent to translucent (not allowing much light to pass through).

Geologically, **iron-rich, dark colored minerals** are separated from **iron-poor, light colored minerals**. This distinction creates two separate subdivisions and speeds identification. It is also logical because most rocks are classified by the percentages of these lighter and darker minerals. Dark colored minerals are sometimes called **ferromagnesian** mineral (rich in iron and magnesium).

Step 2 Separating minerals by color

Place mineral's numbers into the boxes below. **Dark colored minerals** include the following colors: **Black, Brown, Green, Red, dark gray**. **Light colored minerals** include the following, **White, Light Brown, Yellow, Pink, Light gray**. Also list the colors of minerals you consider to have **metallic luster**. Use the following or create your own descriptor for the metallic minerals, Brassy, blued (gun metal), tarnished (like silver), Rusty, Brick red, specular (reflecting light like many mirrors).

Dark Minerals	Light minerals	Metallic minerals or Earthy

3) Hardness– Hardness is defined as resistance to scratching. Commonly geologists and gemologists use a scale created by **Friedrich Mohs** in 1812. It is a relative scale and is based on 10 common minerals arranged from softest 1 to hardest 10. *If a mineral of known hardness can scratch another of unknown hardness, the unknown is softer than the test mineral.* You can bracket a mineral between two known minerals and then state its hardness. A mineral very close in hardness will just barely scratch a test mineral that it is close to. Half hardness definitely scratch the one below and clearly don't scratch the one above.

We will not scratch minerals, but will try to scratch **test materials** of known hardness with the minerals. Choose a sharp, clean, and representative edge or point of the mineral specimen to scrape against the test object. ***Always put the glass plate for testing on the table! Never, ever hold it in your hand while scratching a mineral on it!***

Mohs' Scale of Hardness

1. Talc (softer than skin; feels slippery),
2. Gypsum (fingernail is about 2.5 and easily scratches gypsum, but not calcite = 3)
3. Calcite (a little harder than the average fingernail; a copper penny is 3.5)
4. Fluorite (forms triangles and cubes)
5. Apatite (your teeth are this hard, glass is about 5.5)
6. Orthoclase Feldspar (a pink or white feldspar will just scratch glass; a steel file is about 6.5)
7. Quartz (6 ½ porcelain plate will be scratched by quartz; quartz is found everywhere!)
8. Topaz (varies in color, some is a precious gem)
9. Corundum (includes ruby and sapphire)
10. Diamond (which scratches everything, even other diamonds).

Figure

Many minerals can be bracketed between two test minerals. If you think it is between them in hardness, you say ½. For instance Olivine can scratch orthoclase but not quartz. Today, we don't need to get ½ hardnesses.

Step 3 Separating minerals by hardness

Using the minerals given by your instructor, list the minerals by hardness. Use the 3 categories below. Later when your identify the minerals, refer to these results.

1) Soft. These minerals can be scratched by your fingernail.

2) Intermediate. These minerals **can not** be scratched by a fingernail, but can be scratched using a **steel nail** (soft steel is about 5.5 on Mohs' Scale; though this is the same hardness as glass, if the mineral is close to this hardness, it is much easier to see a scratch on glass).

3) Hard. These minerals can **scratch a glass plate**. It important that you put the glass plate on the table and push the mineral **away from you and others** when you do this test to **avoid injury**.

Hardness table

	Metallic or Earthy	Nonmetalic Dark	Nonmetalic Light
Soft (fingernail)			
Intermediate (steel nail)			
Hard (scratches glass)			

These are only relative hardness and if absolute hardness of diamond is compared to that of corundum it can be up to 150 times harder (diamond's hardness is directional).

Caution! Remember not to test fine mineral or gem samples for hardness unless there is a safe inconspicuous place to scratch. Destructive test are always a bad idea. Never do a hardness test on a cut gem in class. **You can just ask your instructor how hard the cut gem is.**

4) Cleavage and Fracture– Some minerals break with smooth sides when hit by a strong, direct blow. Other minerals will fracture unevenly. A mineral that cleaves with smooth sides will reflect light from the cleavage just as a wristwatch glass does (Have you seen someone shine sunlight around the room with a watch glass? Must have been a boring class). Shiny, reflective sides suggest cleavage, while dull sides of a mineral are usually due to fracture (some metallic minerals may have tarnish that reduces both luster and shine off the surface).

Fracture surfaces are uneven and won't reflect light like a watch glass (see Figure 3).

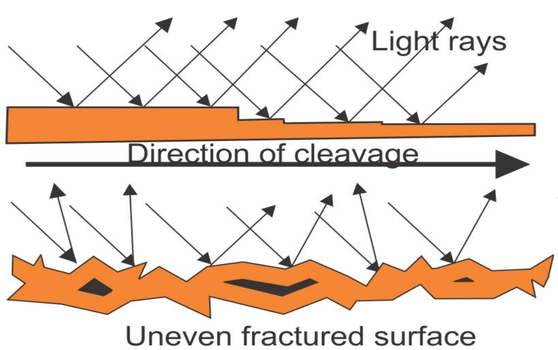


Figure 3. The flat or stepped surfaces of cleavage reflect light all in the same direction, like a mirror. A fractured uneven surface reflects light in all directions. Cleavage shows a strong flash of light when the specimen moves.

<u>A mineral may have both fracture and cleavage</u>. Minerals become flat-sided geometric solids if three (3) or more good cleavages exist. A cube for instance is formed by 3 cleavages at

right(90º) angles to each other (Example: halite). Less than 3 cleavages means at least one fracture surface. Some minerals (Example: quartz) have no cleavage at all!

Cleavage is due to planes of weakness in the mineral's crystalline structure. It is result of bonding and ordering of atoms. It is important, for example in diamond cutting and also can create flaws. A cut gemstone may show a cleavage crack internally. Sometimes a cleavage crack reflects a rainbow of colors.

Look at the **angles** at which the cleavages meet (assume you are looking at mainly cleavage or fracture surfaces in your box samples), are they right angles (like a box), acute angles (less than 90º), or obtuse angles (greater than 90º). Though it is difficult to be precise, you may estimate the actual angle created when two cleavages meet. First list if you see cleavage at all (cleavage = flat and reflective surfaces). A mineral having only one cleavage will make a sheet-like flat mineral, more than one cleavage will make a 3-D or boxy mineral piece.

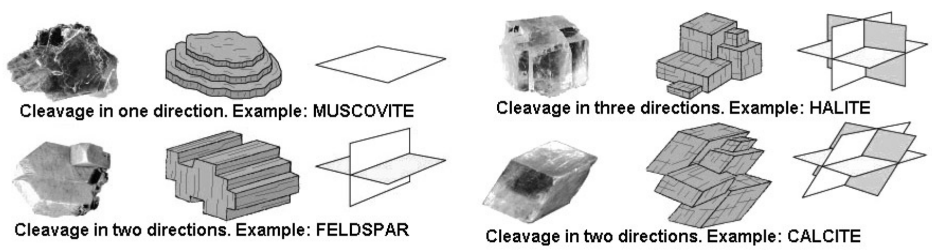


Figure 5. Cleavage directions are not always easy to recognize. These pictures are rather idealized examples.

	Metallic or Earthy	Nonmetalic Dark	Nonmetalic Light
No cleavage			
Cleavage present			
More than one cleavage present (estimate angels)			

Streak–The color of a powdered mineral is called the mineral's streak. Just as when a piece of chalk is drawn across a black board, it leave a streak. Streak is when a mineral is drawn across a porcelain plate. Any mineral that leaves no powder on the plate is harder that the porcelain (6.5 on Mohs' scale, same as a hardened steel file).

Many minerals have a different colored powdered than they do in their crystal or massive form. The color may be entirely different, or it may be a different shade. Look at pyrite, fool's gold, for instance.

Report the color of the powdered mineral on the porcelain plate as streak, as it may differ from the color appearance of the larger specimen. Do not waste the streak plate. Start by doing a few examples suggested by your instructor.

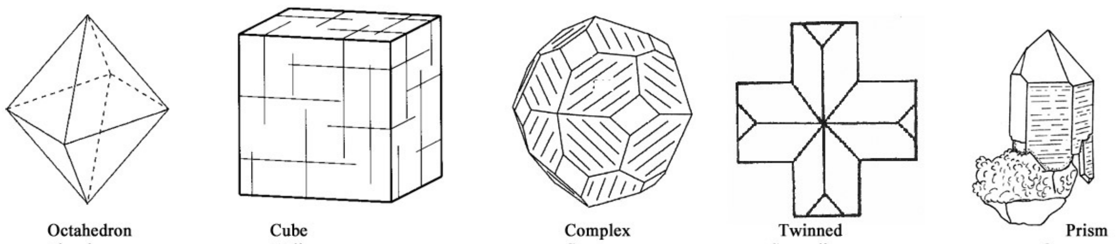
Do minerals with **metallic luster and dark colored nonmetallic minerals**. Light colored minerals' streak are usually not needed for identification.

Report number and color. Start with suggestions from your instructor. You can test other minerals later if you are having trouble ID-ing them.			
	Metallic or Earthy	Nonmetalic Dark	Nonmetalic Light (not important)
Color or if powder but no color = colorless			

Crystal Shape–The shape of a crystal can be a characteristic property. Most minerals crystallize with a particular shape referred to as the mineral's crystal **habit**. The crystal's habit is a result of the internal ordered arrangement of atoms in the mineral's structure.

The habit or shape is formed by flat-sided surfaces referred to as crystal faces. **Crystal faces** are the result of growth of the mineral. A crystal with all flat surfaces bounding it is called **euhedral (unless it is a mineral with perfect cleavage)**. Euhedral crystals are rare and are formed when crystals have room to **grow without interruption**.

Most crystals in a rock hit other growing crystals and do not have flat faces. These irregular crystals are called **anhedral**. If you look at the rock granite, the visible crystals all run into each other, thus every mineral is anhedral (**see side table granite piece**). Crystal shape can be characteristic for a mineral. For instance, beryl often crystallizes in an elongate 6 sided prism(hexagonal prism) with flat ends. One of the most common euhedral minerals seen is quartz. Quartz often forms hexagonal prisms with a pyramid at the tip (termination). If a crystal has flat faces at both ends it is said to be doubly terminated.



Octahedron
Fluorite
Pyrite
Diamond

Cube
Halite
Galena
Pyrite

Complex
Garnet
Leucite

Twinned
Staurolite
Feldspar

Prism
Quartz
Tourmaline
Beryl

Use the illustrations above to identify the unknowns on the side table labeled "crystal shape." Warning! **Do not Scratch these minerals!** Use color and luster plus shape to determine your answers. Note that the minerals are listed in your tables at the back of the chapter and you can look up luster and color there.

	Octahedral shape	Cubic shape	Complex shape	Twinned	Prism
sample #					
your guess at the sample name					

Understanding crystal shape is very important for correctly orienting gems for cutting and polishing. Along with cleavage and fracture the proper orientation of the crystal is important for bringing out the best qualities of a gem.

Auxiliary Test

These tests should only be done if you suspect the mineral might have this property based on looking at the Tables of identification at the back of this chapter. So do not test every mineral with these tests, only use them later. Still become familiar with them for possible later use.

Reaction to Acid–This test is used on minerals that are suspected of being in the carbonate family. A drop of dilute hydrochloric acid is placed on the mineral. If the mineral bubbles, it is a carbonate and the acid has dissolved it and released carbon dioxide (CO_2).

Clean the acid off by drying it with a paper towel immediately after testing. It can stain clothes! ***If you leave an acid soaked mineral in your box, everyone at your table loses a point on the next quiz!!!***

Step 6 As needed check the minerals you suspect may be carbonates with acid.

Specific Gravity (Today = heft)–Basically specific gravity (SG) is a comparison of the weight of a mineral to the weight of an equal volume of water. The resulting number is very much like density (grams/cm^3[a division problem]); however, since you divide grams by grams in specific gravity, the units (grams) cancel out and SG is dimension less (no weight or volume given). SG of minerals are tabulated and usually can be calculated to 1 or 2 decimal places in the lab; for instance quartz has an SG of 2.65 while the metallic mineral galena has an SG of 7.6.

However, we will study SG in a separate lab, but today you can observe **heft**. Heft is the weightiness of an object in your hand. For instance, two oranges of the same approximate size can be tested for heft. The one that feels heavier is juicer. Two minerals of the same size can be hefted and the heavier mineral has a higher SG. Try this for say for two (2) sets of light colored, two dark colored, and several metallic minerals. Put the general results in the table below, remember you are approximating and sort of treating all the minerals as if you are testing oranges for juiciness. So heavy = most heft and light = least heft.

Again, density and specific gravity are basically the same thing and we will use them in later labs. Heft itself may be valuable when comparing say a quartz to a topaz. See the side table for a piece of each. Which is greater heft, Quartz or Topaz.

List of minerals tested for heft_________________.

Heft (approximate density) Report number and approximate heft of the mineral. Try and find minerals of similar size and report heft as light, medium, heavy.			
Only do a few tests. 2 of each mineral color or luster maximum	Metallic or Earthy	Nonmetalic Dark	Nonmetalic light

Magnetic Attraction

Few minerals are attracted to a magnet. Magnetite, an iron mineral, is attracted. Ferrous (iron minerals) are more attracted than nonferrous substances. Some gems, such as synthetic diamonds are attracted to magnets because they have iron inclusions.

Lobestone is a magnetic form of **magnetite** that will hold an iron staple. Find it in your box!

Tenacity

Tenacity is more than just strength, it is essentially overall durability and behavior related to toughness.

Minerals can have tenacity such as being: Brittle, Elasticity (snapping back), Malleable (ability to be hammered into sheets), Ductile (ability to be drawn into a wire), etc.

Interestingly tenacity is not entirely related to hardness, for example topaz is harder than quartz, but breaks more easily because it has cleavage and quartz has no cleavage. Thus most people would suggest that quartz has better tenacity. Gold's tenacity is great for jewelry.

Taste

Salt has a taste as do other nongem minerals. Don't taste minerals! You could get sick.

Smell

A few minerals smell when broken or powdered. Usually sulfur, but also some clays.

Warning! You may need to retest some of these minerals if you do not find a match in the tables. The reason is that poor technique and impurities in the specimens can lead to inaccurate results. Sometimes you should borrow a neighbor's sample just in case!

Transparency

Lean the meanings of **transparent**, **opaque**, and **translucent**.

Luminescence

So minerals give off light when stimulated by: ultraviolet light, heat, pressure, electricity, X-rays, etc. We will study luminescence a little later in the course.

List of materials needed

1) test objects. Glass plates, porcelain plates, steel nails, calcite pieces, hydrochloric acid (7%),

plastic magnifiers, magnets (or staples).

2) demonstration minerals. Quartz crystal, calcite crystal, corundum crystal, tourmaline crystal, models of salt and diamond, wooden models of crystal shapes. Examples of luster. Metallic: pyrite, galena, magnetite, specular hematite. Earthy, oolitic hematite and limonite. Non-metallic: quartz, gypsum, feldspar. Special lusters. Small diamond, tiger's eye, labradorite, Ulexite, fiber ball, amber piece,

3) List of examples needed.

4) quartz and topaz for heft.

5) Luster examples in a box. 1) Greasy- look for opal or chalcedony, 2) Pearly-Ulexite, 3) Earthy oolitic hematite and limonite, 4) Vitreous luster-quartz, 5) Resinous-amber 6) Metallic 7) Schiller (use labradorite)

6) **side table granite piece**

Review Questions and terminology

1) List the important words in defining a mineral.

2) List the important words in defining a gem.

3) What is gem rough?

4) List important physical properties that we test for in the lab.

5) List physical properties tests that are destructive to the mineral/gem samples.

6) How hard is your fingernail, a soft steel nail, a piece of glass, a porcelain plate?

7) On a cut (faceted) gemstone, where is the best place to do a hardness test?

8) Find out, from an outside source, what tarnish is? What may cause it to occur?

9) A flat piece or surface on a mineral is more likely,___________, but could also be__________.

10) Can you explain your answer to question 9 (above)? Why is one more likely?

11) Can a mineral have a cube form only by growing as a cube in the first place?

12) Why would anyone name a trash/garbage bag "Hefty?"

13) Quartz is one of the most common minerals present, you run into it on a beach, in house dust, etc. What property should a gem have in greater/excess than quartz?