Lab 3

Minerals

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LAB 3 Minerals

Learning Objectives

- Define what a mineral is and learn about the physical properties of minerals
- Determine the specific gravity of various unidentified minerals
- Identify several common minerals based on their physical properties

INTRODUCTION

Minerals are the foundation of our planet and our society (we use minerals every day!). Minerals are used to make items like cars (Figure 1), smartphones, building materials, and pencils. They are also essential components of many foods we eat. **All minerals are naturally occurring, inorganic substances with a characteristic chemical composition and a crystalline structure.** A crystalline structure is an orderly 3-D arrangement of atoms (or molecules), and it results in the formation of crystals. Most mineral crystals occur in rocks, which are aggregates of one or more minerals.

Figure 1. The cars we drive are composed of many different types of minerals.

ELEMENTS AND COMPOUNDS

All minerals have a characteristic chemical composition, which means each mineral is made up of a specific combination of chemical elements. The element oxygen (O), for example, makes up almost half of the Earth's crust by weight! Silicon (Si) is the crust's second most abundant element—over one-quarter of the Earth's crust by weight—followed by aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg). These eight elements account for almost all of the total mass of the Earth's crust. Some minerals (e.g., diamonds) are composed of only one element. Most minerals, however, are chemical compounds, which means they contain more than one element. For example, halite (NaCl) (also called "rock salt") is a mineral compound that consists of the elements sodium (Na) and chlorine (Cl)—the same compound that is used to salt your food when cooking (Figure 2).

Figure 2. Halite (NaCl) (on the left) and table salt (on the right) are composed of the same chemical compound.

Figure 3. Blue azurite ($Cu_3(CO_3)_2(OH)_2$) and green malachite ($Cu_2CO_3(OH)_2$) together in the same rock

MINERAL IDENTIFICATION

Each mineral has a unique set of physical and chemical characteristics. Some characteristics are more reliable for identification than others, and a single characteristic should not be solely used to identify a mineral. For example, quartz (SiO_2) can have a transparent, white color, but so can halite (NaCl).

Determination of the internal structure and chemical composition of minerals requires complex laboratory equipment. In this lab, we will discuss how to identify minerals based on a set of physical attributes that are more easily determined. Seven physical properties are commonly used to identify minerals: **color and clarity**, **luster**, **streak**, **hardness**, **crystal habit**, **cleavage or fracture**, and **specific gravity**. Other miscellaneous properties may also be used to distinguish specific minerals (or groups of minerals), and a few of these will be discussed briefly in this lab.

COLOR AND CLARITY

The color of a mineral is usually the first property you notice. Some minerals occur in shades of only one color, like the minerals shown in Figure 3, and some are iridescent (like soap bubbles). However, most minerals occur in more than one color due to chemical variations or impurities. Minerals may also change color when they have been exposed to heat or altered by weathering. Therefore, caution must be used when using color to identify minerals.

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Minerals can also vary in the clarity of the color (or lack of color) they exhibit. They can be **transparent** (clear like window glass), **translucent** (like frosted glass), or **opaque** (solid; light does not travel through it). It is useful to describe minerals in terms of both color and clarity since there can be many variations for the same mineral. For example, quartz (SiO_2) can appear as opaque black (called flint), transparent gray (called smoky quartz), transparent yellow (called citrine), opaque gray (called chert), opaque red or yellow (called jasper), and many other varieties!

Knowledge Check

- [ ] *What are the eight most abundant elements in the Earth's crust?*

LUSTER

Luster refers to the way the surface of a mineral reflects light. All minerals have either a **metallic** or **nonmetallic** luster. A metallic luster looks like the silvery or golden sheen of metals (Figure 4a). A nonmetallic luster (Figure 4b) looks unlike metals, and it is broken down into several other descriptive categories: **earthy or dull** (like dirt or clay; nonreflective), **pearly** (like a pearl), **silky** (like silk or satin cloth), **waxy** (like a candle), **adamantine** (sparkly), or **vitreous** (like glass or a glossy photograph). A summary of common lusters is given in Table 1.

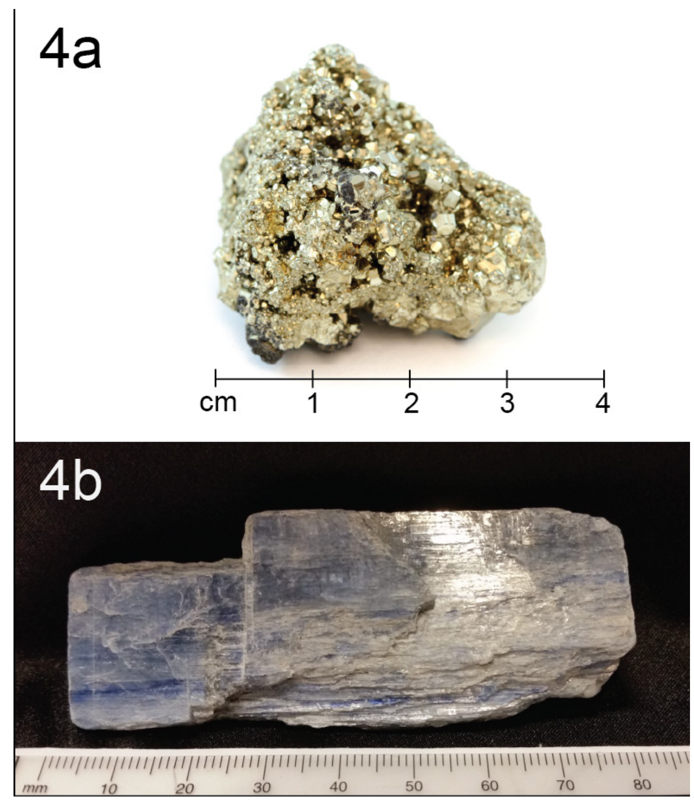

Figure 4. (a) Pyrite (FeS_2), also known as Fools Gold, has a metallic luster. (b) Kyanite (Al_2SiO_5) is a mineral that has a vitreous luster.

STREAK

Streak is the color of a mineral after it has been ground to a fine powder. But this does not mean that you have to grind down the whole mineral sample to find its streak—there is a much simpler (and less destructive) way to find a mineral's streak. Simply scrape the mineral across a piece of unglazed porcelain (known as a **streak plate**), and then blow away any excess powder and fragments. The color of the powder left on the plate is the mineral's streak (Figure 5). So when you write on a chalkboard, you are seeing the streak of the chalk. A streak color may or may not be the same as the mineral's apparent color (Figure 5). For example, all variations of hematite (Fe_2O_3), including both soft and metallic varieties ranging in color from black to gray to red, all have the same red-brown streak. This is why streak is sometimes referred to as a mineral's true color. Note that not all minerals leave a streak when performing a streak plate test. This may be due to the mineral having a hardness higher than that of the streak plate (hardness will be discussed in the next section). For example: quartz (SiO_2) has a white streak, but since quartz is harder than the streak plate, it will only scratch the plate and no color will rub off on the plate. For the purposes of this lab, if a streak does not come off on the streak plate, we will simply state that the mineral does not have a streak.

Figure 5. Pyrite (FeS_2) (on the left) leaves a black streak, whereas rhodochrosite ($MnCO_3$) (on the right) leaves a white streak. Photo by Ra'ike

HARDNESS

Hardness is the measure of a mineral's resistance to scratching. A harder mineral will scratch a softer mineral. Geologists use the **Mohs Hardness Scale** (developed by German mineralogist Friedrich Mohs) to help identify minerals. The Mohs Hardness Scale is a relative scale, where the softest mineral, talc, ($Mg_3Si_4O_{10}(OH)_2$) has a hardness of 1, and the hardest mineral, diamond, (C) has a hardness of 10. The Mohs Hardness Scale is shown in Table 2. Hardness can be tested using common household items. These items include your fingernail, a copper penny (in this case, a copper plate), a steel nail, a glass plate, and a streak plate (all items provided for you, except a fingernail—because that would be gross. Just use one of your own). Recall the discussion of hardness in the streak section. If a mineral is harder than the streak plate (hardness of 6.5), then no streak from the mineral will be present on the plate. Instead, the mineral will scratch the plate. If this occurs in your experiment, you may notice that a white substance appears on the mineral. This is actually the streak of the streak plate appearing on the mineral!

Table 1. Descriptions and Examples of Common Lusters

Luster	Description	Example
Vitreous	Glassy	Quartz (SiO_2)
Resinous	Like tree sap	Sphalerite (ZnS)
Pearly	Iridescent, pearl-like	Talc ($Mg_3Si_4O_{10}(OH)_2$)
Greasy	As if coated by a thin layer of oil	Nepheline ($(Na,K)AlSiO_4$)
Silky	Fine, parallel fibers that looks like silk	Serpentine ($Mg_3Si_2O_5(OH)_4$)
Adamantine	Transparent/translucent with a brilliant luster	Diamond (C)
Dull	Little or no luster	Kaolinite ($Al_2Si_2O_5(OH)_4$)
Waxy	As if coated by a thin layer of wax	Variscite ($Al(PO_4) \cdot 2H_2O$)

Table 2. Mohs Hardness Scale

Hardness	Index Mineral	Common Object
10	**Diamond**	**-**
9	**Corundum**	**-**
8	**Topaz**	**-**
7	**Quartz**	**-**
6.5	**-**	**Streak Plate**
6	**Feldspar**	**Glass Plate**
5.5	**-**	**Steel Nail**
5	**Apatite**	**-**
4	**Fluorite**	**-**
3.5	**-**	**Copper Plate**
3	**Calcite**	
2.5	**-**	**Fingernail**
2	**Gypsum**	**-**
1	**Talc**	**-**

Knowledge Check

☐ ***Is it possible to determine the identity of a mineral if you know only its color? Why or why not?***

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CRYSTAL HABIT

Crystal habit is the characteristic crystal shape that a mineral exhibits if it grows unimpeded. Crystal habit is a purely external feature of crystals. Perfect crystal habits are rare because most minerals do not grow unimpeded, but instead crowd together and form networks of crystals. If a crystal habit is visible, it can be a distinctive property to aid in mineral identification. Some of the most common crystal habits are shown in Figure 6.

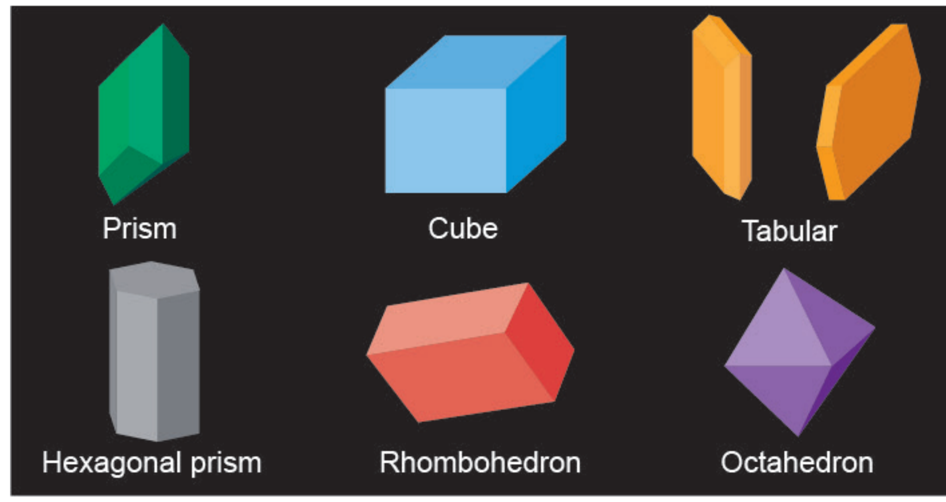


Figure 6. An example of some common crystal habits. The flat surfaces of these habits are known as crystal faces.

CLEAVAGE AND FRACTURE

The way a mineral breaks is another useful physical characteristic that aids in mineral identification. Minerals break along **cleavage** surfaces (flat) or **fracture** surfaces (curved). Cleavage surfaces occur as a result of parallel planes of weakness between repeating, parallel layers of atoms in a crystal. The chemical bonding, or attraction, between these layers is weak and is easily broken. These planes of weakness are referred to as cleavage planes. Each cleavage plane displays an orientation relative to a mineral's crystalline structure, called a cleavage direction. The number of cleavage planes, and the cleavage direction, is used to describe a mineral's cleavage. For example, halite (NaCl) has three cleavage planes at 90 degrees to each other, causing it to break into cubes that have sides at right angles to each other (Figure 7). This is called cubic cleavage. The quality of a mineral's cleavage (essentially, the smoothness) is also commonly noted. Cleavage can be *excellent*, with large, even, flat surfaces; *good*, with small, uneven, flat surfaces; *poor*, with a few small, flat surfaces; or *absent*, with no flat surfaces. If cleavage is absent, then a mineral fractures (breaks into irregular masses). There are several different types of fracture, but we will not cover all of them in this lab. A good example of a mineral that fractures is quartz (SiO_2). When quartz (SiO_2) breaks, it tends to fracture along smoothly curved surfaces, like when glass breaks. This type of fracture pattern is known as **conchoidal fracture**. Figure 8 shows an example of conchoidal fracture in quartz.

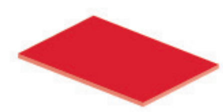
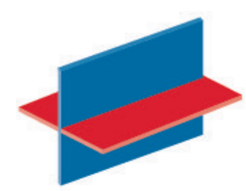
# Cleavage Directions	Cleavage Planes	Example Minerals	Notes
1		Muscovite Talc	"Basal" cleavage. Looks like books that split along sheets
2 (at 90°)		Feldspars Pyroxenes	"Prismatic" cleavage. Makes elongated forms with rectangular cross sections.
2 (not at 90°)		Amphiboles	"Prismatic" cleavage. Makes elongated forms with parallelogram cross sections.
3 (at 90°)		Halite Galena	"Cubic" cleavage. Makes cubes (and parts of cubes).
3 (not at 90°)		Calcite Dolomite	"Rhombohedral" cleavage. Makes rhombohedrons (and parts of rhombohedrons).

Figure 7. Common cleavage directions and the shapes that a crystal breaks into.

SPECIFIC GRAVITY

Specific gravity is a unitless value derived by dividing the density of a mineral by the density of water. Since specific gravity is a unitless number, it is useful for comparing different substances to each other. A geologist can gain some insight into the specific gravity of one mineral compared to another by **hefting**. To do this, hold one mineral in one hand, and then hold an equal-sized piece of the second mineral in your other hand. This allows you to compare the difference in weight between the two samples. The mineral that feels heavier has the higher specific gravity. Galena (PbS) is a good example of a mineral with a high specific gravity. Galena is a lead sulfide, and lead is a very heavy element!

Figure 8. Pure quartz (SiO_2)breaks along smooth, curved surfaces—known as conchoidal fracture.

Knowledge Check

☐ *What are the seven most common properties used to identify minerals?*

OTHER PROPERTIES

Other miscellaneous properties include taste, feel, smell, magnetism, and effervescence. Does the mineral taste salty? Then it may be halite, a mineral composed of sodium chloride (NaCl). You may recognize this as table salt. Does the mineral have a soap-like texture? This is talc. If it smells like eggs, you are probably looking at sulfur. Minerals such as magnetite have magnetic properties and may slightly attract, or be attracted to, metals. Effervescence is a basic chemical test that involves placing a drop of hydrochloric acid (HCl), or in this lab acetic acid ($C_2H_4O_2$), onto a mineral. If the mineral effervesces (fizzes), then the mineral contains calcium carbonate ($CaCO_3$). This test is commonly used to determine if a mineral is calcite ($CaCO_3$).

Did You Know?

To be classified as a gemstone, a mineral must be judged beautiful, durable, and rare. However, it must also be at least a 7 on the Mohs scale if used for jewelry. Diamonds, the hardest of gemstones, are judged by their color (even a clear diamond is graded into nine shades), clarity (purity of stone), cut (the way the stone is cut to display light), and carat (weight). Rubies, composed of corundum (Al_2O_3), get their red coloring from traces of chromium. Blue sapphires are also composed of corundum (Al_2O_3) and get their color from trace mixtures of iron (Fe), titanium (Ti), and chromium (Cr). The elements beryllium (Be), aluminum (Al), silicon (Si), and oxygen (O) form the mineral beryl ($Be_3Al_2(SiO_3)_6$) (pictured on the right), whose variations include emerald and aquamarine.

Exercise 1

Evaluating Specific Gravity

Exercise Inventory

Materials

Mineral Box (Minerals A–I)

*Water

*Paper or cloth towels

Labware

250 mL Graduated Cylinder

Digital Scale

Note: You must provide the materials listed in *red.

EXERCISE 1: EVALUATING SPECIFIC GRAVITY

Specific gravity is the density of a substance divided by the density of another substance, usually water. For example, if the specific gravity of quartz is 2.65, then the weight of quartz is 2.65 times that of an equal volume of water. This gives you a single number that's useful because it allows density comparisons of many different types of minerals. In this lab, you will determine the specific gravity of several unknown minerals.

Important! Minerals A–I will also be used for Exercise 2. It is very important to keep track of your minerals.

PROCEDURE

- [ ] 1. Open the Minerals box and line up the minerals in alphabetical order according to the letters given on the mineral.
- [ ] 2. Turn on the scale by pressing the button labeled 0/T. If your scale does not turn on, you may have to remove the battery cover and remove a small strip of plastic from the battery housing. Once the scale is on, press the 0/T button a second time to zero the scale. Make sure that the units are in grams (g). If not, press the M button until the units displayed are in grams. **Key Technique**
- [ ] 3. Weigh Mineral A on the scale. Record the "Dry Mass (g)" of Mineral A in Table 3 on the Exercise 1 Data Sheet.
- [ ] 4. Fill the 250 mL graduated cylinder with 100 mL of water. Be very precise with your measurement of 100 mL, and measure the volume from the meniscus. Not measuring the volume properly will result in an inaccurate measurement and lead to incorrect answers for the rest of your exercise. Always be sure to measure volume of a liquid from the meniscus.
  Key Technique
- [ ] 5. Place the mineral in the graduated cylinder and record the "Total Volume (mL)" of water in Table 3 on the Exercise 1 Data Sheet. If the mineral does not fit, do not force the mineral into the cylinder. Please contact eScience Labs to receive a replacement mineral if your mineral sample does not fit.
- [ ] 6. Subtract 100 mL from the Total Volume. This number is the displaced volume. Record the "Displaced Volume (mL)" in Table 3 on the Exercise 1 Data Sheet.

- [ ] 7. To determine the mineral's specific gravity, divide the "Dry Mass (g)" of the mineral by the "Displaced Volume (mL)." This value gives you the density. Since the specific gravity of the mineral is its density divided by 1 g/mL (the density of water), the units cancel out and the specific gravity is the density of the mineral without any units. Record this number under the "Specific Gravity" column in Table 3 on the Exercise 1 Data Sheet.
- [ ] 8. Carefully dump out the water and Mineral A. Set Mineral A aside on a paper or cloth towel and allow it to dry (you will use the mineral again in Exercise 2).
- [ ] 9. Repeat Steps 3–8 for remaining minerals B–I.
- [ ] 10. Use the data you collected to answer the question on the Exercise 1 Data Sheet.

Data Sheet

Exercise 1 Data Sheet

Table 3. Specific Gravity

Mineral Letter	Dry Mass (g)	Total Volume (mL)	Displaced Volume (mL)	Specific Gravity
A				
B				
C				
D				
E				
F				
G				
H				
I				

Use Table 3 to answer the following question:

Which mineral had the highest specific gravity? What does this tell you about the elements (or compounds) that make up this mineral?

Hint: Think about how elements are arranged on the periodic table based on their properties.

Exercise 2 Mineral Identification

Exercise Inventory

Materials

Mineral Box (Minerals A–I)

Hand Lens

Copper Plate

Streak Plate

Steel Nail

Glass Plate

Acetic Acid

(1) Pipette

*Fingernail

Note: You must provide the materials listed in *red.

EXERCISE 2: MINERAL IDENTIFICATION

In this exercise, you will observe the physical properties of a set of unknown minerals, and then use these observations to identify the minerals.

PROCEDURE

Exercise Demo

- [ ] 1. Record the color and clarity of one of your mineral samples in Table 5 on the Exercise 2 Data Sheet. Remember, some minerals may have more than one color.
- [ ] 2. Determine the luster of your mineral, and record your observation in Table 5 on the Data Sheet. If you determine that the mineral has a nonmetallic luster, note whether it is earthy/dull, pearly, silky, waxy, greasy, or vitreous.
- [ ] 3. Determine the streak color of your mineral by scraping it on the streak plate. Use only a small section of the streak plate, because you will be using it for each mineral. Record the streak color in Table 5 on the Data Sheet.

  Note: **The streak test works only for minerals softer than the streak plate. If the mineral is harder than the streak plate, it will not leave behind any color. The streak plate has a hardness of about 6.5.**

- [ ] 4. Test the hardness of your mineral by using the Mohs Hardness Scale (Table 2). Begin by trying to scratch the glass plate with the mineral. If the mineral scratches the glass, then the mineral is harder than 6.0. If it does not scratch the glass, keep going down the list of items on the Mohs Scale until you are able to scratch one of the items (or one of the items can scratch the mineral). Record your findings in Table 5 on the Data Sheet.

  Remember: ***If a mineral scratches an object, it is harder than the object. If the object scratches the mineral, it is harder than the mineral.***

- [ ] 5. Determine the cleavage of your mineral. If the mineral has no planes of cleavage, then it fractures. You may need to use a hand lens to determine cleavage/fracture. Refer back to Figure 7 in the lab section as a guide to help you identify cleavage planes. Record your observations in Table 5 on the Data Sheet.

☐ 6. Record any other distinctive characteristics you encounter. For example: If you suspect a mineral is calcite, place a couple drops of acetic acid (with a pipette) onto the mineral surface and watch for effervescence. Evidence of effervescence would go in the column titled “Other Distinctive Properties” in Table 5.

  Note: **If you choose to use the acetic acid, be sure to wear the gloves supplied in your safety kit. Acetic acid is not strong enough to cause damage to your home or the environment, but it can irritate skin. The acetic acid can be rinsed off the mineral in the sink.**

☐ 7. Repeat Steps 1–6 for the rest of the mineral samples.

☐ 8. After you have tested all of the minerals and recorded your observations, compare your findings to the minerals and properties listed in Table 4 to identify the unknown minerals. List the names of each mineral in the last column of Table 5.

☐ 9. Use your findings to answer the questions on the Data Sheet.

Table 4. Minerals and Their Properties

Mineral Name	Color/Clarity	Luster	Streak	Hardness	Cleavage	Crystal Habit	Other Distinctive Properties
Biotite $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	Black to dark brown/ transparent to translucent	Vitreous	Gray-brown	2.5–3	One (perfect)	Tabular	Easily splits into thin sheets
Calcite $CaCO_3$	Colorless, white, yellow, brown, pink/ transparent to translucent	Vitreous to iridescent	White	3	Three not at 90°	Massive, rhombohedral, prismatic	Effervesces in acid
Dolomite $(Ca,Mg)(CO_3)_2$	White, gray, or pink/ usually opaque	Vitreous	White	3.5–4	Three not at 90°	Massive, rhombohedral	Effervesces in acid when powdered
Fluorite CaF_2	Colorless to yellow, green, blue, pink, purple/transparent to translucent	Vitreous	White	4	Octahedral (4)	Cubes, octahedral, or dodecahedral	Fluorescent when exposed to ultraviolet radiation
Galena PbS	Silver-gray/opaque	Metallic	Gray to dark gray	2.5	Three at 90°	Cubic	Very heavy
Gypsum $CaSO4•2H_2O$	Colorless, white, gray/ transparent to translucent	Vitreous or silky	White	2	One (perfect)	Tabular, massive, prismatic	Sometimes fluorescent in ultraviolet light
Halite NaCl	Colorless, white, yellow, brown/transparent to translucent	Vitreous	White	2.5	Three at 90°	Cubic	Tastes salty; very light
Muscovite $KAl_2(AlSi_3)O_{10}(OH)_2$	Colorless, yellow, brown/ transparent to translucent	Vitreous	White	2–2.5	One (perfect)	Tabular	Easily splits into thin sheets
Plagioclase Feldspar $(Na,Ca)AlSi_3O_8$	Colorless, white, gray/ opaque	Vitreous; may be iridescent	White	6	Two at 90°	Prismatic	Commonly shows fine, parallel striations
Potassium Feldspar $KAlSi_3O_8$	White, pink, orange, brown/ opaque	Vitreous	White	6	Two at 90°	Prismatic	Frequently twinned
Pyrite FeS_2	Brassy yellow, gold/ opaque	Metallic	Greenish black	6–6.5	Uneven fracture	Cubic, octahedral;	Heavy; sparks if struck with a hammer
Quartz SiO_2	Colorless, white, (may occur in all colors)/ transparent to translucent	Vitreous to greasy	White	7	Conchoidal fracture	Prismatic, massive	Scratches glass
Talc $Mg_3Si_4O_{10}(OH)_2$	White to pale green/ opaque	Pearly or greasy	White	1	One (perfect)	Tabular	Makes thin flakes; feels soapy

Data Sheet

Exercise 2 Data Sheet

Table 5. Mineral Identification

Mineral Sample	Color/Clarity	Luster	Streak	Hardness	Cleavage	Other Distinctive Properties	Name of Mineral
A							
B							
C							
D							
E							
F							
G							
H							
I							

Data Sheet

Exercise 2 Data Sheet

1. What properties of Mineral B could be used to distinguish it from gold?

Write the name of Mineral B, its common nickname (see Figure 4) and fill in the data about each of the properties. Compare the differences between the two minerals and summarize your findings in a short paragraph. Is the nickname accurate? Why or why not?

Properties of native gold:

- **Color/Clarity**: Opaque yellow
- **Luster**: Metallic
- **Streak**: Yellow
- **Hardness**: 2.5–3
- **Cleavage**:Absent (ductile and malleable)
- **Specific Gravity**: 19.3

Properties of Mineral B:

Name_____________ **Nickname**_____________

- **Color/Clarity**: ____________
- **Luster**: ____________
- **Streak**: ____________
- **Hardness**:____________
- **Cleavage**:____________
- **Specific Gravity**: ____________

2. Marble is a rock that is composed primarily of the carbonate minerals calcite ($CaCO_3$) and dolomite ($Ca,Mg(CO_3)_2$). In Exercise 2, you saw the way carbonate minerals react to a drop of acetic acid. Based on this observation, why do you think people who care for monuments and sculptures made of marble are concerned about acid rain?