# Lab 3

## Minerals - Rock Ingredients

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## Learning Objectives

- Relate chemical elements to minerals
- Explain and perform qualitative assessments to identify minerals
- Explain and perform quantitative assessments to identify minerals

## Introduction

Minerals can be found throughout the world on the surface of or below the Earth's crust. They also may be extraterrestrial in origin. Building blocks of all rocks, minerals are naturally occurring inorganic solids. That is, they form naturally, are not made from plants or animals, and they are neither a liquid nor a gas.

## Chemical Elements

All minerals have a definite chemical composition, which means each mineral is made of specific chemical elements. The element oxygen, for example, makes up almost half of the Earth's crust. Silicon is the Earth's second most abundant element - over one-quarter of the Earth's crust by weight, followed by aluminum, iron, calcium, sodium, potassium, and magnesium. These eight elements account for almost all of the total mass of the Earth's crust.

Each element consists of atoms. The smallest particle of a substance that can exist by itself, atoms consists of a nucleus of protons and neutrons. Orbiting around the atom nucleus are electrons. Figure 1 shows the atomic structure of the element iron, which along with element nickel, comprise the Earth's core.


***Figure 1:* Atomic structure of iron.**

## *Knowledge Check*

☑ *Since this course will be studying the Earth's crust and the rocks upon it, what are the eight elements that make up most of the Earth's crust?*

## Compounds

Some minerals may have one chemical element: they contain only one type of atom. Most minerals are chemical compounds, which means they contain atoms of more than one chemical element. The atoms connect to form molecules, groups of two or more atoms. For example, halite, also called rock salt, is a mineral compound which consists of the same molecules which are used to salt your food when cooking.

The molecules stack together in patterns to form a crystal. Arising from a gas, liquid, or solid, these crystals grow from the addition of similar materials. In a mineral's ordered atomic arrangement, chemical elements arrange in a unique geometric pattern repeated over and over, layer by layer.

## Mineral Identification

### *Crystal Symmetry*

Determining a mineral's **crystal symmetry** is one way of identifying a mineral. For example, both the diamond and graphite are made of the chemical carbon but their atoms arrange differently. In graphite, carbon items link in a layered arrangement with wide spaces which makes it one of the softest minerals, while the linkage of less carbon atoms in a diamond makes it the strongest.

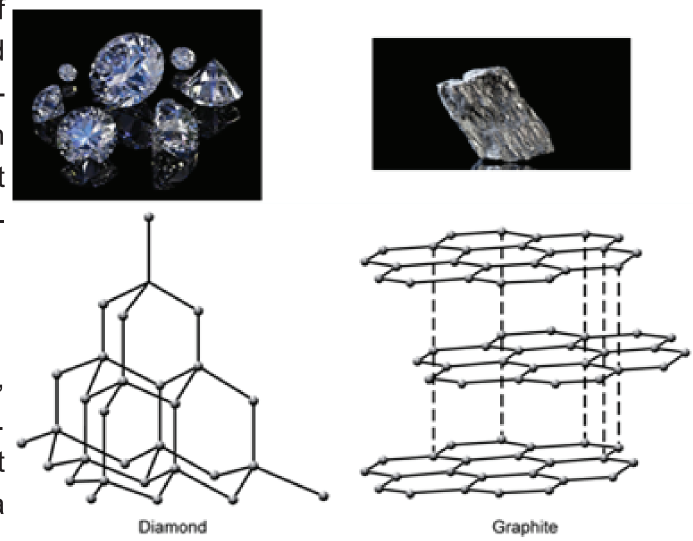


***Figure 2:* Crystal structures of graphite vs. diamond.**

Crystals grow through different processes. In magma, atoms arrange in orderly patterns as the rock cools. Crystal symmetry structures are a useful starting point for mineral identification because each mineral has a definite crystal structure. For example, quartz forms a hexagonal crystal with six sides, and halite, which is cubic, forms a perfect cube.

***Figure 3:* Crystal symmetry in halite (left) and quartz (right).**

Hand samples of crystal reflect their inner symmetry by how their crystals are arranged. Crystals that commonly develop prisms have a **prismatic/columnar** habit. Crystals that grow in flat plans are **tabular**, and crystals with no visible structure are called **massive**.

Because minerals grow through crystallization, they are the same throughout. When rock is molten, mineral molecules combine to form rocks. To be more precise, **rock** can be defined as the solid mineral material forming part of the surface of the earth and other similar planets, exposed on the surface or underlying soil or oceans.

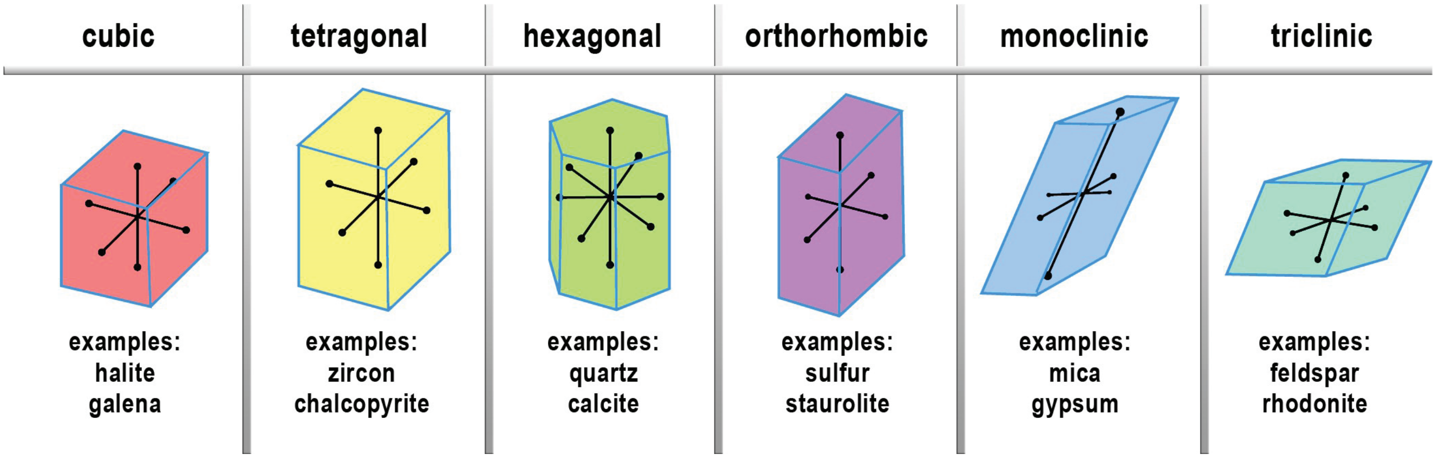


***Figure 4:*** ***Crystal symmetry. Can you identify the cubic and hexagonal symmetries presented in halite and quartz in Figure 3?***

### Coloration

You can also classify minerals by color. For example, the mineral malachite is always green. Azurite is usually blue and sulfur is usually yellow. Notice the use of "usually"? A mineral's color can change if it has been exposed to heat, has some impurities, or possesses other properties that don't change the mineral's basic make-up.

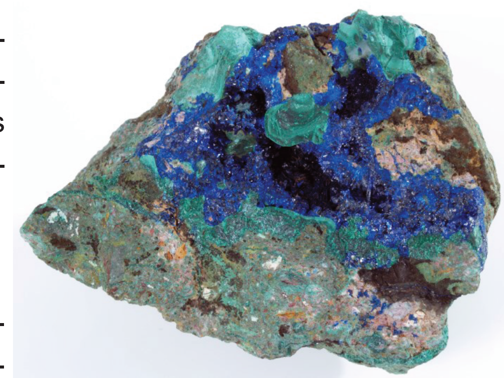

***Figure 5:*** ***Blue azurite and green malachite (minerals) together in a rock.***

Blue azurite is presented in Figure 5. However, the green color is malachite, which shows an identification complication: the existence of different minerals in one rock. Besides one mineral being different colors, different minerals can be the same color. Three minerals, for example, look like the mineral gold in color.

***Figure 6:*** ***Pyrite, $FeS_2$, is the most common sulfide mineral.***

Pyrite, a mineral commonly mistaken for gold, also has the same gold-like appearance of chalcopyrite. Further. weathered biotite mica also can be mistaken for gold, which brings up another identification problem: exposure to weather can affect a mineral's surface color.

Surfaces also can be dark, pale, dull, shiny, streaked, speckled, banded, and other descriptors. So, while surface color is an easy property for which to look, geologists also use additional properties to identify minerals.

### *Luster*

The way the surface interacts with or reflects light - **luster** - is another way to distinguish minerals. A geologist first looks to see whether a mineral has a metallic (i.e., looks like metal such as silver, gold, or copper) or non-metallic luster. They then check to see if a mineral is dull (clay-like), pearly, silky, waxy, adamantine (sparkly), resin (similar to tree sap), or vitreous (glassy). Of course, unlike determining mineral color, figuring out luster isn't always easy. Since about 70 percent of minerals have a vitreous luster, notably silicates, carbonates, phosphates, sulfates, halides, and hydroxides, that's one luster to look for!

***Figure 7:* Fluorite has a vitreous (glassy) luster.**

### *Knowledge Check*

☑ *How is color different from luster?*

## Up Close...

**For centuries, rubies from the mountainous jungle area of Myanmar have been prized for their red, fluorescent "pigeon blood" color and transparency. Found in marble and river gravel, the rubies formed at high temperatures within the Earth and can be mined in several ways. One common method involves blasting gravel with high-pressurized water that separates lighter stones from heavier ones. Miners then search the residue and harvest the rubies.**

### *Cleavage*

**Cleavage,** the look of a mineral when it evenly breaks, is another identification clue. Cleavage is displayed when a mineral splits leaving parallel planes. These breaks occur where a rock is weak within the crystalline structure, and therefore reveals internal structure. Cleavage can be measured by quality, smoothness, roughness, or number of cleavage planes. If there is more than one plane, the angles between cleavages are helpful in diagnoses. Not all minerals have cleavage. Instead they may have **fractures** (rough, uneven breaks in the structure). Therefore, this can be a tricky identification property.

### *Streak*

The streak - the mark a mineral leaves when rubbed on a tile of unglazed white porcelain - is often used in mineral identification. A streak color may be similar to the mineral's apparent color; or, it may be unexpected. For example, fluorite can have a few different colored crystals, but it leaves a white streak. Additionally, black hematite streaks red.

*Other Characteristics*

Does the mineral let light through (transparency)? Only some light (translucent)? Or not any light (opaque)? That's an identifier. Is it magnetic? The mineral magnetite is. Even smell is used to identify minerals. In normal temperatures, for instance, sulfur smells like a lit match. When heated, it and pyrite, both have a rotten egg smell.

## Mineral Identification Tests

Besides studying a mineral by eye, simple tests are used for identification. Hydrochloric acid (or, even less acidic acids such as acetic or citric acid) interacts with calcium carbonate and thus identifies calcite, aragonite, and vaterite because these minerals effervesce (i.e., fizz) when carbon dioxide ($CO_2$) is released. However, this test has its exceptions because certain minerals emit such a weak amount of gas that a magnifying glass is needed to see it bubble. The effervescence may also disappear very quickly; or, the mineral may need to be crushed to a powder for the reaction to proceed.

**Table 1: Mohs Hardness Test**

| Hardness | Test | Index Mineral |
|---|---|---|
| 1 | Scratch with a fingernail | Talc |
| 2 | Scratch with a fingernail | Gypsum |
| 3 | Scratch with a copper penny | Calcite |
| 4 | Scratch with a knife | Fluorite |
| 5 | Scratch with a steel nail | Apatite |
| 6 | Scratches glass | Feldspar |
| 7 | Scratches glass | Quartz |
| 8 | Scratches glass | Topaz |
| 9 | Scratches glass | Corundum |
| 10 | Scratches glass | Diamond |

## Mohs Test

A mineral's hardness - its bonding strength between atoms - has long been used in identification. Frederick Mohs devised a scratch test in 1822 to determine a mineral's hardness that is still used today. The softest mineral rates 1 on the scale, and the hardest rates 10. Each scale mineral only can scratch one of a lower number. This is a relative scale. Keep in mind, this test is similar to some mineral property tests in that minerals don't always neatly fit into each hardness category.

Table 2: Common Minerals and their Properties

| Mineral | Color | Luster | Streak | Hardness | Crystal Habit | Specific gravity |
|---|---|---|---|---|---|---|
| Biotite | Brown-black, black | Pearly | White | 2.5 | Platey/Tabular | 2.8 |
| Dolomite | White, grey, pink | Vitreous, pearly | White | 3.5 | Massive | 2.8 |
| Galena | Silvery grey | Metallic | Dark grey | 2.6 | Cubic | 7.4 |
| Gypsum | Colorless, white | Vitreous, silk, waxy | White | 2 | Massive | 2.3 |
| Muscovite | White, grey | Pearly | White | 2.5 | Platey/Tabular | 2.8 |
| Olivine | Olive Green | Vitreous | White or pale green | 6.5 | Massive | 3.3 |
| Plagioclase albite | White, grey | Vitreous | White | 6 | Massive | 2.6 |
| Potassium feldspar | Pink | Vitreous, Pearly | White | 6 | Elongated tabular | 2.6 |
| Pyrite | Brass-yellow | Metallic | Greenish-Black or Brownish-Black | 6 | Cubic | 4.8 |
| Quartz | Yellow, white, grey | Non-metallic, vitre-ous | White | 7.0 | Hexagonal | 2.7 |
| Talc | White, green, grey | Dull, greasy | White | 1.0 | Rare | 2.7 |

## Up Close...

**To be classified as a gemstone, a mineral must be judged beautiful, durable, and rare. However, it must also to be at least a 7 on Mohs scale if used for jewelry. The diamond, the hardest of gemstones, is judged by its 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, formed from the mineral corundum, get their red coloring from traces of chromium. Blue sapphires also are made from corundum with coloring from trace mixtures of iron, titanium, and chromium. The elements beryllium, aluminum, silicon, and oxygen form the mineral beryl (pictured to the right) from which emeralds come. Trace elements of chromium and vanadium give emeralds their green color while different trace elements in beryl produce the semiprecious stone aquamarine. Beryl can also present different colors based on the oxidation state of its chemical makeup.**

### *Knowledge Check*

☑ *A mineral with a hardness of 4.5 can scratch which reference minerals on Moh's Scale?*

To precisely determine some minerals, laboratory instruments may have to be used, and the mineral itself crushed, cut, or subjected to other destruction. However, a step-by-step examination provides clues that can help identify many minerals and also illustrate mineral characteristics.

### Common Minerals

Learning about minerals facilitates understanding regarding the rocks around us. See Table 2 for some common minerals found in the Earth's crust and their properties.

### Pre-Lab Questions:

1. Name at least four mineral properties used in identification.

2. Is a mineral a rock? Use scientific reasoning to explain why, or why not.

3. What are several words used to describe the crystal habit of hand samples?

4. What are several words used to describe the luster of hand samples?

## Experiment 1: Mineral Identification

A series of property tests provide clues to unidentified minerals. In this experiment, you will develop qualitative and quantitative observations; and, make inferences about minerals by examining properties that lead to mineral identification.

Important! Minerals A - G will also be used for Experiment 2. It is very important to keep the minerals organized with their letter. For example, be sure to remember which mineral is labeled as Mineral A, Mineral B, etc...

### Materials

Hand Lens

Copper Plate (H = 3.5 on Mohs Scale)

Glass Plate (H = 5.5)

- Mineral A
- Mineral B
- Mineral C
- Mineral D
- Mineral E
- Mineral F
- Mineral G

Steel Nail (H ≈ 6.5)

Streak Plate

## Procedure

1. Record color of each mineral sample in Table 3. Remember, minerals may have more than one color. Be sure to record all observations.
2. Determine the luster (e.g., metallic [glassy, shiny, bright, etc.] or non-metallic [dull, Earth-like]) of each mineral, and record your findings in Table 3.
3. Determine the mineral's streak by gently dragging it on the streak plate. What is the color left behind? Record the streak color in Table 3.

   Note: The streak test only works for minerals softer than the streak plate. If the mineral is harder than the streak plate, it won't leave behind any color. A streak plate has a hardness of about 6.5.
4. Test the hardness of each mineral (starting with Mineral A, and proceeding all the way through Mineral H) using the Mohs Scale. To do this, begin by trying to scratch the glass plate with the mineral. If it scratches the glass, it's harder than 5.5. If it doesn't, keep going down the list of items on the Mohs Scale. Record your findings in Table 3.

   Remember: If a mineral scratches an object, it is harder than the object.
5. If possible, determine the crystal structure of each mineral. You may need to use the hand lens to accomplish this step. Record your findings in Table 3.
6. If possible, determine the cleavage of each mineral. This is often one of the most difficult characteristics for mineralogists to determine. Study the surface of the mineral to determine if there are any noticeable cleaved edges. Often times there will be signs of cleavage on the surface, however, if there is not, chip off a small piece of the mineral using the nail (wear your safety glasses!). Be sure to remove only a small piece of the mineral and to do it gently. Additional research may help in determining cleavages. Record your observations in Table 3.
7. Record any remaining observations in the column titled "Other" in Table 3.
8. After all of the minerals have been tested and results have been recorded, compare your findings to Table 2 (see the Introduction) to determine mineral identification.

   Note: You will complete the column titled "Chemical" during the Post-Lab Assessment.

Table 3: Mineral Identification

| Mineral Letter | Color | Luster | Streak Color | Hardness | Crystal Habit | Mineral Name | Chemical | Other |
|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | |
| B | | | | | | | | |
| C | | | | | | | | |
| D | | | | | | | | |
| E | | | | | | | | |
| F | | | | | | | | |
| G | | | | | | | | |

## Post-Lab Questions

1. Which of the identification properties did you find most useful? Least useful? Explain why.

2. Why is color alone not a good identifier for minerals?

3. Research and record the chemical composition of each mineral (e.g., Gypsum = $CaSO_4$) in the final column of Table 3.

4. Is water a mineral? Explain why or why not.

## Experiment 2: Evaluating Specific Gravity

Specific gravity is the density of a substance compared to another substance, usually relative to 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. Density tells how tightly packed the molecules are inside each substance. 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 minerals.

## Materials

250 mL Beaker
- Mineral A
- Mineral B
- Mineral C
- Mineral D
- Mineral E
- Mineral F
- Mineral G

Scale

*Water

*You Must Provide

## Procedure

1. Line up minerals in alphabetical order (according to the letters assigned on the mineral bag by eScience Labs)
2. Weight the mineral on the scale. Record the dry weight of Mineral A in Table 4.
3. Fill the 250 mL beaker with 100 mL of water.
4. Place the mineral in the beaker and record the total volume of water.
5. Subtract 100 mL from the volume recorded in Step 4 to calculate the displaced volume.
6. To determine the mineral's specific gravity, divide its dry weight by the displaced volume. Divide this by the density of water (1.00 g/mL). Record the answer in "Specific Gravity."
7. Repeat the same procedure for each remaining minerals.

| Mineral Letter | Dry Mass (g) | Total Volume (water + mineral) (mL) | Displaced volume (mL) | Specific Gravity |
|---|---|---|---|---|
| A | | | | |
| B | | | | |
| C | | | | |
| D | | | | |
| E | | | | |
| F | | | | |
| G | | | | |

Table 4: Specific Gravity

## Post-Lab Questions

1. Which mineral had the highest specific gravity? Which had the lowest?

2. Why is it helpful to measure the specific gravity of a mineral?

3. The Earth's crust is composed mostly of the minerals quartz, calcite, and feldspar with specific gravity around 2.75. Which minerals in this experiment had a specific gravity of approximately 2.75?

4. Must mineral specimens be pure (only one mineral) when determining specific gravity?