Minerals

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CHAPTER 1 Minerals

Lesson Objectives

- Describe the properties that all minerals share.
- Describe some different crystal structures of minerals.
- Identify the groups in which minerals are classified.

Vocabulary

- atom
- chemical compound
- crystal
- compound
- electron
- element
- ion
- matter
- mineral
- molecule
- neutron
- nucleus
- proton
- silicate

Introduction

You use objects that are made from minerals every day, even if you do not realize it. You are actually eating a mineral when you eat food that contains salt. You are drinking from a mineral when you drink from a glass. You might wear silver jewelry. The shiny metal silver, the white grains of salt, and the clear glass may not seem to have much in common, but they are all made from minerals (**Figure** 1.1). Silver is a mineral. Table salt is the mineral halite. Glass is produced from the mineral quartz.

Just looking at that list you see that minerals are very different from each other. If minerals are so different, what do all minerals have in common?

What is Matter?

To understand minerals, we must first understand matter. **Matter** is the substance that physical objects are made of.

FIGURE 1.1

Silver is used to make sterling silver jewelry. Table salt is the mineral halite. Glass is produced from the mineral quartz.

Atoms and Elements

The basic unit of matter is an **atom**. At the center of an atom is its **nucleus**. **Protons** are positively charged particles in the nucleus. Also in the nucleus are **neutrons** with no electrical charge. Orbiting the nucleus are tiny electrons. **Electrons** are negatively charged. An atom with the same number of protons and electrons is electrically neutral. If the atom has more or less electrons to protons it is called an **ion**. An ion will have positive charge if it has more protons than electrons. It will have negative charge if it has more electrons than protons.

An atom is the smallest unit of a chemical **element**. That is, an atom has all the properties of that element. All atoms of the same element have the same number of protons.

Molecules and Compounds

A **molecule** is the smallest unit of a **chemical compound**. A compound is a substance made of two or more elements. The elements in a chemical compound are always present in a certain ratio.

Water is probably one of the simplest compounds that you know. A water molecule is made of two hydrogen atoms and one oxygen atom (**Figure** 1.2). All water molecules have the same ratio: two hydrogen atoms to one oxygen atom.

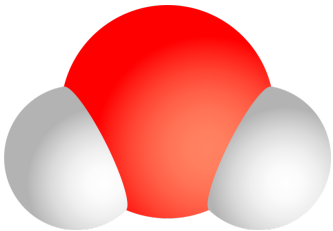

FIGURE 1.2

A water molecule has two hydrogen atoms (shown in gray) bonded to one oxygen molecule (shown in red).

What are Minerals?

A **mineral** is a solid material that forms by a natural process. A mineral can be made of an element or a compound. It has a specific chemical composition that is different from other minerals. One mineral's physical properties differ from others'. These properties include crystal structure, hardness, density and color. Each is made of different elements. Each has different physical properties. For example, silver is a soft, shiny metal. Salt is a white, cube-shaped crystal. Diamond is an extremely hard, translucent crystal.

Natural Processes

Minerals are made by natural processes. The processes that make minerals happen in or on the Earth. For example, when hot lava cools, mineral crystals form. Minerals also precipitate from water. Some minerals grow when rocks are exposed to high pressures and temperatures.

Could something like a mineral be made by a process that was not natural? People make gemstones in a laboratory. Synthetic diamond is a common one. But that stone is not a mineral. It was not formed by a natural process.

Inorganic Substances

A mineral is an inorganic substance. It was not made by living organisms. Organic substances contain carbon. Some organic substances are proteins, carbohydrates, and oils. Everything else is inorganic. In a few cases, living organisms make inorganic materials. The calcium carbonate shells made by marine animals are inorganic.

Definite Composition

All minerals have a definite chemical makeup. A few minerals are made of only one kind of element. Silver is a mineral made only of silver atoms. Diamond and graphite are both made only of the element carbon.

Minerals that are not pure elements are made of chemical compounds. For example, the mineral quartz is made of the compound silicon dioxide, or SiO_2. This compound has one atom of the element silicon for every two atoms of the element oxygen.

Each mineral has its own unique chemical formula. For example, the mineral hematite has two iron atoms for every three oxygen atoms. The mineral magnetite has three iron atoms for every four oxygen atoms. Many minerals have very complex chemical formulas that include several elements. However, even in more complicated compounds, the elements occur in definite ratios.

Solid Crystals

Minerals must be solid. For example, ice and water have the same chemical composition. Ice is a solid, so it is a mineral. Water is a liquid, so it is not a mineral.

Some solids are not crystals. Glass, or the rock obsidian, are solid but not crystals. In a **crystal**, the atoms are arranged in a pattern. This pattern is regular and it repeats. **Figure** 1.3 shows how the atoms are arranged in halite (table salt). Halite contains atoms of sodium and chlorine in a pattern. Notice that the pattern goes in all three dimensions.

The pattern of atoms in all halite is the same. Think about all of the grains of salt that are in a salt shaker. The atoms are arranged in the same way in every piece of salt.

Sometimes two different minerals have the same chemical composition. But they are different minerals because they have different crystal structures. Diamonds are beautiful gemstones because they are very pretty and very hard.

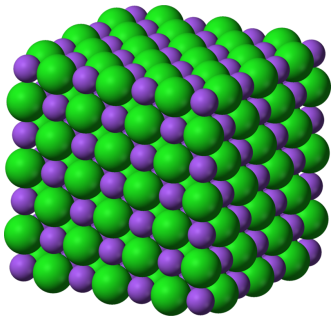

FIGURE 1.3

Sodium ions (purple balls) bond with chloride ions (green balls) to form halite crystals.

Graphite is the "lead" in pencils. It's not hard at all! Amazingly, both are made just of carbon. Compare the diamond with the pencil lead in **Figure** 1.4. Why are they so different? The carbon atoms in graphite bond to form layers. The bonds between each layer are weak. The carbon sheets can just slip past each other. The carbon atoms in diamonds bond together in all three directions. This strong network makes diamonds very hard.

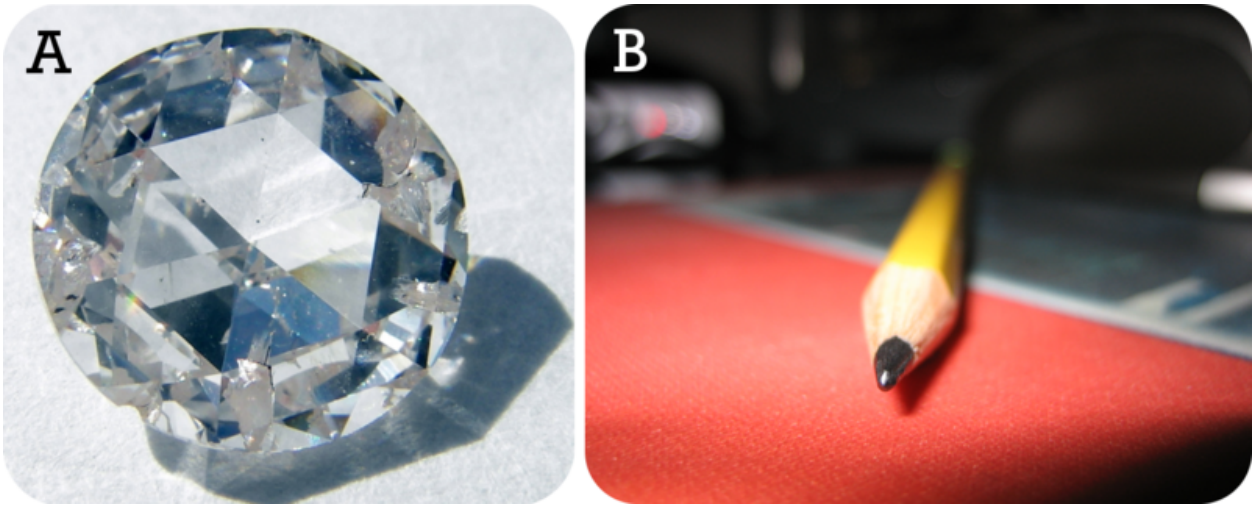

FIGURE 1.4

Diamonds (A) and graphite (B) are both made of only carbon, but they're not much alike.

Physical Properties

The patterns of atoms that make a mineral affect its physical properties. A mineral's crystal shape is determined by the way the atoms are arranged. For example, you can see how atoms are arranged in halite in **Figure** 1.3. You can see how salt crystals look under a microscope in **Figure** 1.5. Salt crystals are all cubes whether they're small or large.

Other physical properties help scientists identify different minerals. They include:

- Color: the color of the mineral.
- Streak: the color of the mineral's powder.

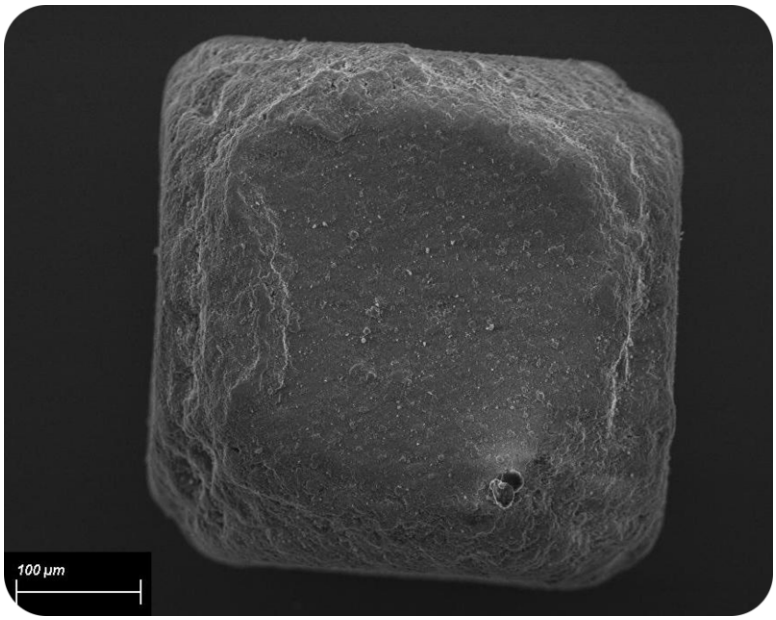

FIGURE 1.5
Under a microscope, salt crystals are cubes.

- Luster: the way light reflects off the mineral's surface.
- Specific gravity: how heavy the mineral is relative to the same volume of water.
- Cleavage: the mineral's tendency to break along flat surfaces.
- Fracture: the pattern in which a mineral breaks.
- Hardness: what minerals it can scratch and what minerals can scratch it.

Groups of Minerals

Imagine you are in charge of organizing more than 100 minerals for a museum exhibit. People can learn a lot more if they see the minerals together in groups. How would you group the minerals together in your exhibit?

Mineralogists are scientists who study minerals. They divide minerals into groups based on chemical composition. Even though there are over 4,000 minerals, most minerals fit into one of eight mineral groups. Minerals with similar crystal structures are grouped together.

Silicate Minerals

About 1,000 silicate minerals are known. This makes silicates the largest mineral group. Silicate minerals make up over 90 percent of Earth's crust!

Silicates contain silicon atoms and oxygen atoms. One silicon atom is bonded to four oxygen atoms. These atoms form a pyramid (**Figure** 1.6). The silicate pyramid is the building block of silicate minerals. Most silicates contain other elements. These elements include calcium, iron, and magnesium.

Silicate minerals are divided into six smaller groups. In each group, the silicate pyramids join together differently. The pyramids can stand alone. They can form into connected circles called rings. Some pyramids link into single and double chains. Others form large, flat sheets. Some join in three dimensions.

Feldspar and quartz are the two most common silicates. In beryl, the silicate pyramids join together as rings. Biotite is mica. It can be broken apart into thin, flexible sheets. Compare the beryl and the biotite shown in **Figure** 1.7.

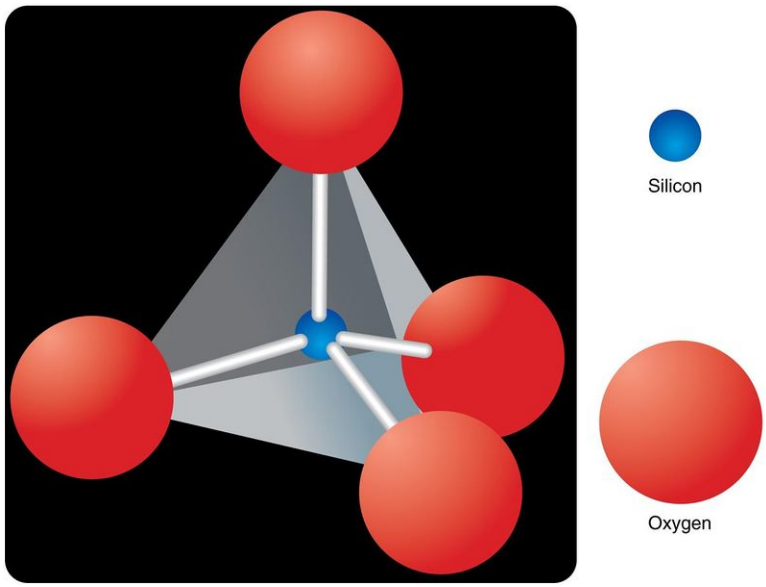

FIGURE 1.6

One silicon atom bonds to four oxygen atoms to form a pyramid

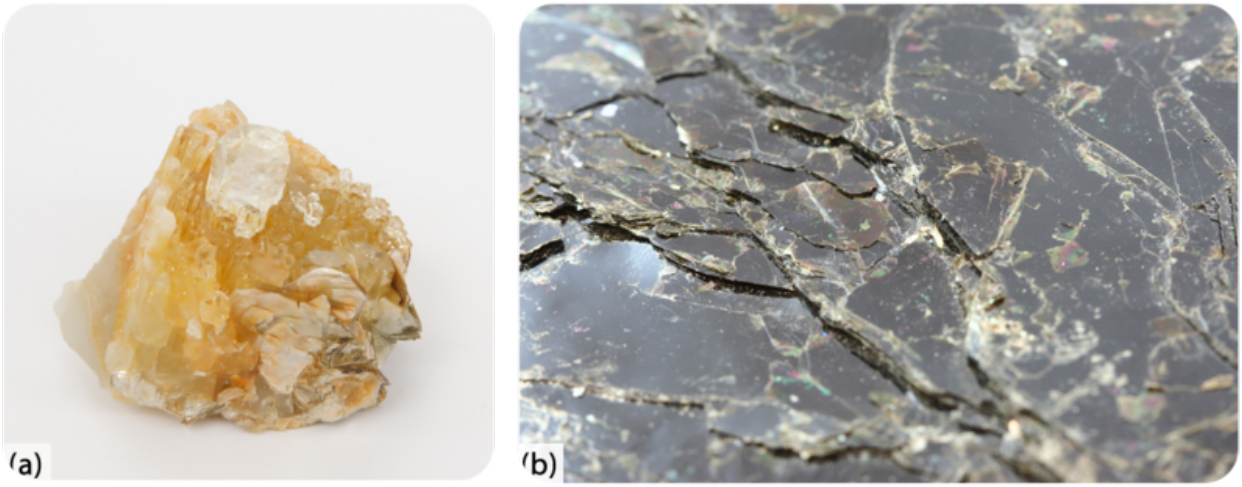

FIGURE 1.7

Beryl (a) and biotite (b) are both silicate minerals.

Native Elements

Native elements contain only atoms of one type of element. They are not combined with other elements. There are very few examples of these types of minerals. Some native elements are rare and valuable. Gold, silver, sulfur, and diamond are examples.

Carbonates

What do you guess **carbonate** minerals contain? If you guessed carbon, you would be right! All carbonates contain one carbon atom bonded to three oxygen atoms. Carbonates may include other elements. A few are calcium, iron, and copper.

Carbonate minerals are often found where seas once covered the land. Some carbonate minerals are very common. Calcite contains calcium, carbon, and oxygen. Have you ever been in a limestone cave or seen a marble tile? Calcite is in both limestone and marble. Azurite and malachite are also carbonate minerals, but they contain copper instead of calcium. They are not as common as calcite. They are used in jewelry. You can see in **Figure** 1.8 that they are very colorful.

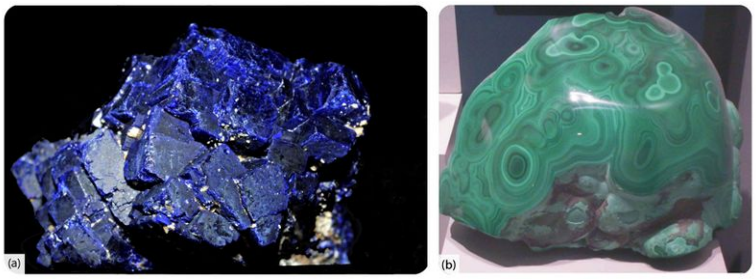

FIGURE 1.8

The deep blue mineral is azurite and the green is malachite. Both of these carbonate minerals are used for jewelry.

Halides

Halide minerals are salts. They form when salt water evaporates. This mineral class includes more than just table salt. Halide minerals may contain the elements fluorine, chlorine, bromine, or iodine. Some will combine with metal elements. Common table salt is a halide mineral that contains the elements chlorine and sodium. Fluorite is a type of halide that contains fluorine and calcium. Fluorite can be found in many colors. If you shine an ultraviolet light on fluorite, it will glow!

Oxides

Earth's crust contains a lot of oxygen. The oxygen combines with many other elements to create oxide minerals. Oxides contain one or two metal elements combined with oxygen. Oxides are different from silicates because they do not contain silicon. Many important metals are found as oxides. For example, hematite and magnetite are both oxides that contain iron. Hematite (Fe_2O_3) has a ratio of two iron atoms to three oxygen atoms. Magnetite (Fe_3O_4) has a ratio of three iron atoms to four oxygen atoms. Notice that the word "magnetite" contains the word "magnet". Magnetite is a magnetic mineral.

Phosphates

Phosphate minerals have a structure similar to silicates. In silicates, an atom of silicon is bonded to oxygen. In phosphates, an atom of phosphorus, arsenic, or vanadium is bonded to oxygen. There are many types of phosphate mineral, but still phosphate minerals are rare. The composition of phosphates is complex. For example, turquoise contains copper, aluminum, and phosphorus. The stone is rare and is used to make jewelry.

Sulfates

Sulfate minerals contain sulfur atoms bonded to oxygen atoms. Like halides, they can form in places where salt water evaporates. Many minerals belong in the sulfate group, but there are only a few common sulfate minerals. Gypsum is a common sulfate mineral that contains calcium, sulfate, and water. Gypsum is found in various forms. For example, it can be pink and look like it has flower petals. However, it can also grow into very large white crystals. Gypsum crystals that are 11 meters long have been found. That is about as long as a school bus! Gypsum also forms at the Mammoth Hot Springs in Yellowstone National Park, shown in **Figure** 1.9.

FIGURE 1.9

Gypsum is the white mineral that is common around hot springs. This is Mammoth Hot Springs in Yellowstone National Park.

Sulfides

Sulfides contain metal elements combined with sulfur. Sulfides are different from sulfates. They do not contain oxygen. Pyrite is a common sulfide mineral. It contains iron combined with sulfur. Pyrite is also known as “fool’s gold.” Gold miners have mistaken pyrite for gold because pyrite has a greenish gold color.

Lesson Summary

- A mineral is a naturally occurring inorganic solid. It has a definite composition and crystal structure.
- The atoms in minerals are arranged in regular, repeating patterns.
- These patterns are responsible for a mineral's physical properties.
- Minerals are divided into groups. The groups are based on their chemical composition.
- Silicates are the most common minerals.

Lesson Review Questions

Recall

1. What is matter?
2. What are atoms and what are they made of?
3. What is a molecule? What substances do molecules make?
4. Go through the eight mineral groups. List the elements that are contained by all minerals in each group.

Apply Concepts

5. Quartz is made of one silicon atom and two oxygen atoms. If you find a mineral and find that it is made of one silicon atom and one oxygen atom is it quartz?
6. Why is water ice considered a mineral?
7. A shady looking character offers you a valuable mineral made of carbon. You know that diamonds are made of carbon so you give him $100 for one. Have you gotten yourself a good deal? Why or why not?

Think Critically

8. Why are diamonds "a girls best friend?" What other uses might diamonds have?
9. Coal is made of ancient plant parts that were squeezed together and heated. Is coal a mineral? Explain.

Points to Consider

- What is one way you could tell the difference between two different minerals?
- Why would someone want to make minerals when they are found in nature?
- Why are minerals so colorful? Can color be used to identify minerals?

References

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