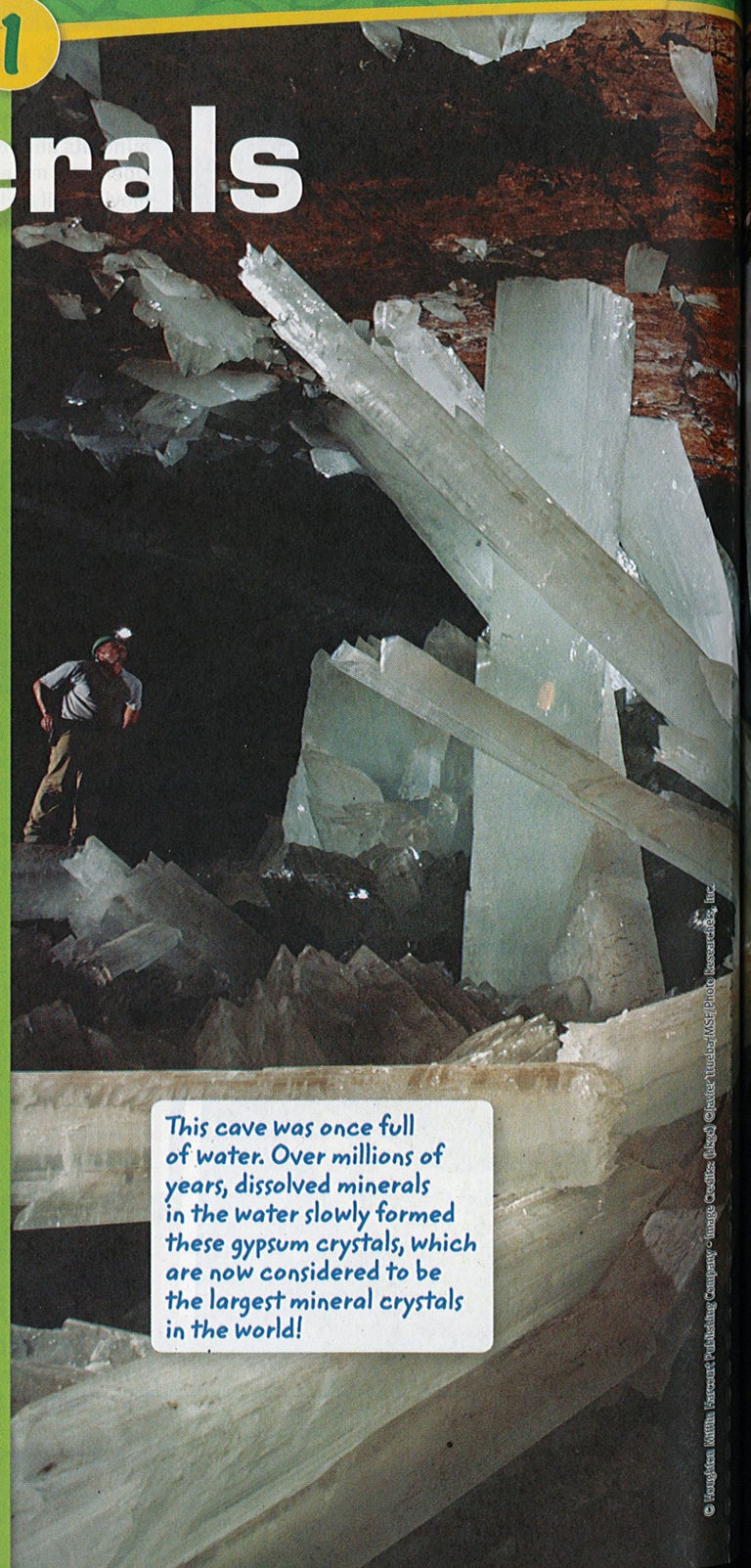
Lesson 1

Minerals

ESSENTIAL QUESTION

What are minerals, how do they form, and how can they be identified?

By the end of this lesson, you should be able to describe the basic structure of minerals and identify different minerals by using their physical properties.



This cave was once full of water. Over millions of years, dissolved minerals in the water slowly formed these gypsum crystals, which are now considered to be the largest mineral crystals in the world!

Lesson Labs

Quick Labs
- Cooling Rate and Crystal Size
- Scratch Test

Exploration Lab
- Intrinsic Identification of Minerals

Engage Your Brain

1 Identify Which of the materials listed below is a mineral?

Yes	No	
☐	☐	ice
☐	☐	gold
☐	☐	wood
☐	☐	diamond
☐	☐	table salt

2 Explain Describe how you think the minerals in the picture below may have formed.

Active Reading

3 Synthesize Many of this lesson's vocabulary terms are related to each other. Locate the terms in the Glossary and see if you can find connections between them. When you find two terms that are related to each other, write a sentence using both terms in a way that shows the relationship. An example is done for you.

Example Sentence
Each element is made of only one kind of atom.

Vocabulary Terms

- mineral
- element
- atom
- compound
- matter
- crystal
- streak
- luster
- cleavage

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Animal, Vegetable, or Mineral?

What do minerals have in common?

When you hear the word *mineral,* you may think of sparkling gems. But, in fact, most minerals are found in groups that make up rocks. So what is a mineral? A **mineral** is a naturally occurring, usually inorganic solid that has a definite crystalline structure and chemical composition.

Definite Chemical Composition

To understand what a definite chemical composition is, you need to know a little about elements. **Elements** are pure substances that cannot be broken down into simpler substances by ordinary chemical means. Each element is made of only one kind of atom. All substances are made up of atoms, so **atoms** can be thought of as the building blocks of matter. Stable particles that are made up of strongly bonded atoms are called *molecules.* And, if a substance is made up of molecules of two or more elements, the substance is called a **compound.**

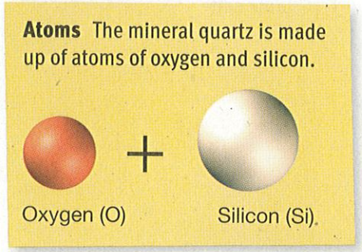
The chemical composition of a mineral is determined by the element or compound that makes up the mineral. For example, minerals such as gold and silver are composed of only one element. Such a mineral is called a *native element.* The mineral quartz is a compound in which silicon atoms can each bond with up to four oxygen atoms in a repeating pattern.

Inquiry

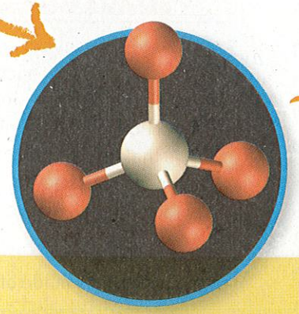
5 Synthesize What is the relationship between elements, atoms, and compounds?

Solid

Matter is anything that has volume and mass. *Volume* refers to the amount of space an object takes up. For example, a golf ball has a smaller volume than a baseball does. Matter is generally found in one of three states: solid, liquid, or gas. A mineral is a solid—that is, it has a definite volume and shape. A substance that is a liquid or a gas is not a mineral. However, in some cases its solid form is a mineral. For instance, liquid water is not a mineral, but ice is because it is solid and has all of the other mineral characteristics also.



Atoms The mineral quartz is made up of atoms of oxygen and silicon.



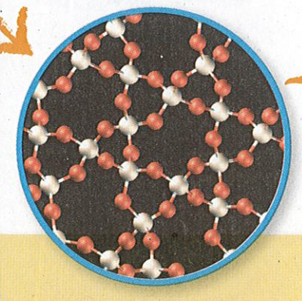
Compound An atom of silicon can typically bond with up to four oxygen atoms to form a molecule. One or more of these molecules form a compound.

Usually Inorganic

Most substances made by living things are categorized as organic substances, such as kidney stones and wood. However, a few substances made by animals, such as clam shells, are categorized as inorganic. An inorganic substance is usually one that is not made up of living things or the remains of living things. And, although a few organic substances such as kidney stones are categorized as minerals, most minerals are inorganic. And, unlike clam shells, most of the processes that form minerals usually take place in the non-living environment.

Crystalline Structure

Minerals have a crystalline structure because they are composed of crystals. A **crystal** is a solid, geometric form that results from a repeating pattern of atoms or molecules. A crystal's shape is produced by the arrangement of the atoms or molecules within the crystal. This arrangement is determined by the kinds of atoms or molecules that make up the mineral and the conditions under which it forms. All minerals can be placed into crystal classes according to their specific crystal shape. This diagram shows how silica compounds can be arranged in quartz crystals.



Crystal Structure In crystals, molecules are arranged in a regular pattern.

Mineral Crystal Billions of molecules arranged in a crystalline structure form these quartz crystals.

Naturally Occurring

Minerals are formed by many different natural processes that occur on Earth and throughout the universe. On Earth, the mineral halite, which is used for table salt, forms as water evaporates and leaves behind the salt it contained. Some minerals form as molten rock cools. Talc, a mineral that can be used to make baby powder, forms deep in Earth as high temperature and pressure change the rock. Some of the other ways in which minerals form are on the next page.

6 Classify Circle *Y* for "yes" or *N* for "no" to determine whether the two materials below are minerals.

	Cardboard	Topaz
Definite chemical composition?	Y (N)	(Y) N
Solid?	Y N	(Y) N
Inorganic?	Y N	Y N
Naturally occurring?	Y N	Y N
Crystalline structure?	Y (N)	Y N
Mineral?	Y N	Y N

Crystal Clear!

How are minerals formed?

Minerals form within Earth or on Earth's surface by natural processes. Recall that each type of mineral has its own chemical makeup. Therefore, which types of minerals form in an area depends in part on which elements are present there. Temperature and pressure also affect which minerals form.

As Magma and Lava Cool

Many minerals grow from magma. Magma—molten rock inside Earth—contains most of the types of atoms that are found in minerals. As magma cools, the atoms join together to form different minerals. Minerals also form as lava cools. Lava is molten rock that has reached Earth's surface. Quartz is one of the many minerals that crystallize from magma and lava.

Visualize It!

7 Compare How are the ways in which pluton and pegmatite minerals form similar?

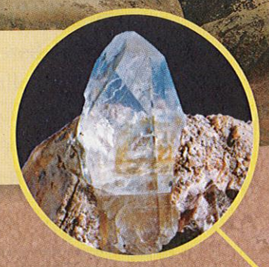
_____

_____

By Metamorphism

Temperature and pressure within Earth cause new minerals to form as bonds between atoms break and reform with different atoms. The mineral garnet can form and replace the minerals chlorite and quartz in this way. At high temperatures and pressures, the element carbon in rocks forms the mineral diamond or the mineral graphite, which is used in pencils.

Cooling Magma Forms Plutons As magma rises, it can stop moving and cool slowly. This forms rocks like this granite, which contains minerals like quartz, mica, and feldspar.



Cooling Magma Forms Pegmatites Magma that cools very slowly can form pegmatites. Some crystals in pegmatites, such as this topaz, can grow quite large.

Metamorphism Minerals like these garnets form when temperature and pressure causes the chemical and crystalline makeup of minerals to change.

From Solutions

Water usually has many substances dissolved in it. As water evaporates, these substances form into solids and come out of solution, or *precipitate*. For example, the mineral gypsum often forms as water evaporates. Minerals can also form from hot water solutions. Hot water can dissolve more materials than cold water. As a body of hot water cools, dissolved substances can form into minerals such as dolomite, as they precipitate out of solution.

8 Summarize Describe three ways minerals form.

A _____

_____

B _____

_____

C _____

_____

Precipitating from an Evaporating Solution When a body of salt water evaporates, minerals such as this halite precipitate and are left behind on the shoreline.

Precipitating from a Cooling Solution on Earth's Surface Dissolved materials can come out of a solution and accumulate. Dolomite, can form this way.

Precipitating from a Cooling Solution Beneath Earth's Surface Water works its way downward and is heated by magma. It then reacts with minerals to form a solution. Dissolved elements, such as gold, precipitate once the fluid cools to form new mineral deposits.

Think Outside the Book

9 Apply Find out what your state mineral is and how it forms.

Sort It Out

How are minerals classified?

The most common classification of minerals is based on chemical composition. Minerals are divided into two groups based on their composition. These groups are the silicate (SIL'ih•kayt) minerals and the nonsilicate (nawn•SIL'ih•kayt) minerals.

Silicate Minerals

Silicon and oxygen are the two most common elements in Earth's crust. Minerals that contain a combination of these two elements are called *silicate minerals.* Silicate minerals make up most of Earth's crust. The most common silicate minerals in Earth's crust are feldspar and quartz. Most silicate minerals are formed from basic building blocks called *silicate tetrahedrons.* Silicate tetrahedrons are made of one silicon atom bonded to four oxygen atoms. Most silicate minerals, including mica and olivine, are composed of silicate tetrahedrons combined with other elements, such as aluminum or iron.

Active Reading **10 Explain** Why is Earth's crust made up mostly of silicate minerals?

_____

_____

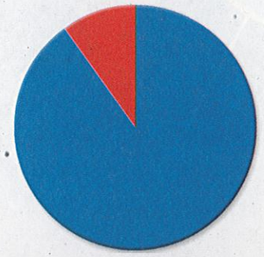
Nonsilicate Minerals

Minerals that do not contain the silicate tetrahedron building block form a group called the *nonsilicate minerals.* Some of these minerals are made up of elements such as carbon, oxygen, fluorine, iron, and sulfur. The table on the next page shows the most important classes of nonsilicate minerals. A nonsilicate mineral's chemical composition determines its class.

Do the Math **You Try It**

11 Calculate Calculate the percent of non-silicates in Earth's crust to complete the graph's key.

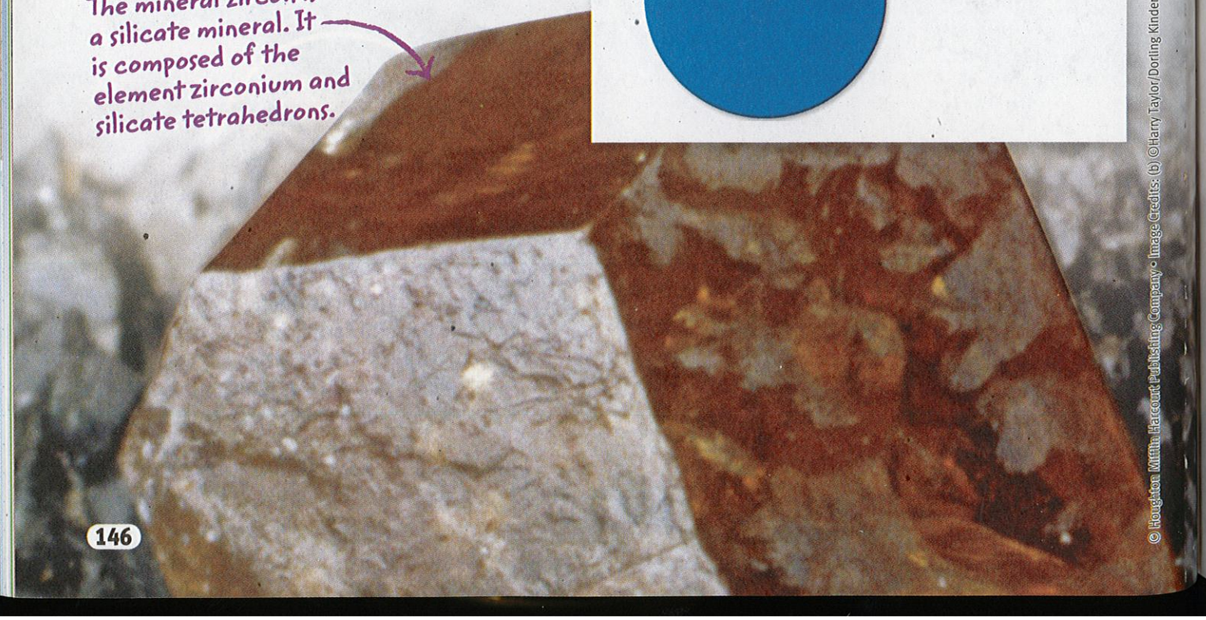
Minerals in Earth's Crust



Silicates 90%

Non-silicates _____%

The mineral zircon is a silicate mineral. It is composed of the element zirconium and silicate tetrahedrons.



Classes of Nonsilicate Minerals

Native elements are minerals that are composed of only one element. Copper (Cu) and silver (Ag) are two examples. Native elements are often used to make electronics.

Silver, Ag

Carbonates are minerals that contain carbon (C) and oxygen (O) in the form of the carbonate ion CO_3^{2-}. We use carbonate minerals in cement, building stones, and fireworks.

Calcite, $CaCO_3$

Halides are compounds that form when elements such as fluorine (F) and chlorine (Cl), combine with elements such as calcium (Ca). Halides are used in the chemical industry and in detergents.

Fluorite, CaF_2

Oxides are compounds that form when an element, such as aluminum (Al) or iron (Fe), combines with oxygen. Oxide minerals are used to make abrasives, aircraft parts, and paint.

Corundum, Al_2O_3

Sulfates are minerals that contain sulfur (S) and oxygen (O) in the form of the sulfate ion SO_4^{2-}. Sulfates are used in cosmetics, toothpaste, cement, and paint.

Barite, $BaSO_4$

Sulfides are minerals that contain one or more elements, such as lead (Pb), or iron (Fe), combined with sulfur (S). Sulfide minerals are used to make batteries and medicines.

Pyrite, FeS_2

Visualize It!

12 Classify Examine the chemical formulas for the two minerals at right. Classify the minerals as a silicate or nonsilicate. If it is a nonsilicate, also write its class.

Gypsum, $CaSO_4 \cdot 2H_2O$

_____

_____

Kyanite, Al_2SiO_5

_____

_____

Name That Mineral!

What properties can be used to identify minerals?

If you closed your eyes and tasted different foods, you could probably determine what the foods are by noting properties such as saltiness or sweetness. You can also determine the identity of a mineral by noting different properties. In this section, you will learn about the properties that will help you identify minerals.

Color

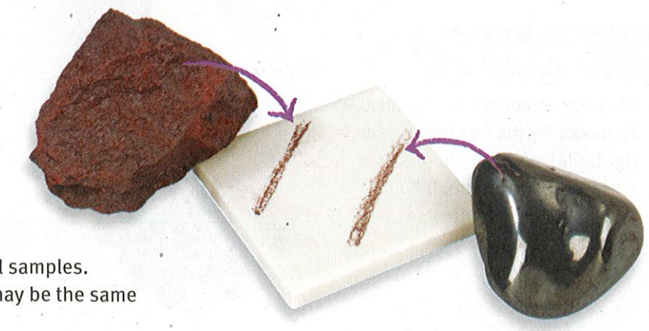
The same mineral can come in different colors. For example, pure quartz is colorless. However, impurities can make quartz pink, orange, or many other colors. Other factors can also change a mineral's color. Pyrite is normally golden, but turns black or brown if exposed to air and water. The same mineral can be different colors, and different minerals can be the same color. So, color is helpful but usually not the best way to identify a mineral.

Active Reading

13 Identify Underline the name of the property on this page that is most reliable for identifying a mineral.

Streak

The color of the powdered form of a mineral is its **streak**. A mineral's streak is found by rubbing the mineral against a white tile called a *streak plate*. The mark left is the streak. A mineral's streak is not always the same as the color of the mineral, but all samples of the same mineral have the same streak color. Unlike the surface of a mineral, the streak is not affected by air or water. For this reason, streak is more reliable than color in identifying a mineral.



Visualize It!

14 Evaluate Look at these two mineral samples. What property indicates that they may be the same mineral?

Mineral Lusters

Luster

The way a surface reflects light is called **luster**. When you say an object is shiny or dull, you are describing its luster. The two major types of luster are metallic and nonmetallic. Pyrite has a metallic luster. It looks as if it is made of metal. A mineral with a nonmetallic luster can be shiny, but it does not appear to be made of metal. Different types of lusters are shown above.

Cleavage and Fracture

The tendency of a mineral to split along specific planes of weakness to form smooth, flat surfaces is called **cleavage**. When a mineral has cleavage, it breaks along flat surfaces that generally run parallel to planes of weakness in the crystal structure. For example, mica tends to split into parallel sheets. Many minerals, however, do not break along cleavage planes. Instead, they fracture, or break unevenly, into pieces that have curved or irregular surfaces. Scientists describe a fracture according to the appearance of the broken surface. For example, a rough surface has an irregular fracture, and a curved surfaces has a conchoidal (kahn•KOY•duhl) fracture.

Visualize It!

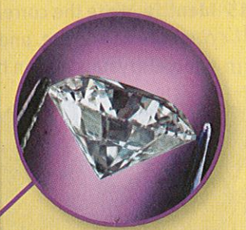
15 Identify Write the correct description, either *cleavage* or *fracture*, under the two broken mineral crystals shown here.

Mohs Scale

1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite
6 Feldspar
7 Quartz
8 Topaz
9 Corundum
10 Diamond

Your fingernail has a hardness of about 2.5, so it can scratch talc and gypsum.

A steel file has a hardness of about 6.5. You can scratch feldspar with it.



Diamond is the hardest mineral. Only a diamond can scratch another diamond.

Visualize It!

16 Determine A mineral can be scratched by calcite but not by a fingernail. What is its approximate hardness?

Density

If you pick up a golf ball and a table-tennis ball, which will feel heavier? Although the balls are of similar size, the golf ball will feel heavier because it is denser. *Density* is the measure of how much matter is in a given amount of space. Density is usually measured in grams per cubic centimeter. Gold has a density of 19 g/cm^3. The mineral pyrite looks very similar to gold, but its density is only 5 g/cm^3. Because of this, density can be used to tell gold from pyrite. Density can also be used to tell many other similar-looking minerals apart.

Hardness

A mineral's resistance to being scratched is called its *hardness*. To determine the hardness of minerals, scientists use the Mohs hardness scale, shown at left. Notice that talc has a rating of 1 and diamond has a rating of 10. The greater a mineral's resistance to being scratched, the higher its hardness rating. To identify a mineral by using the Mohs scale, try to scratch the surface of a mineral with the edge of one of the 10 reference minerals. If the reference mineral scratches your mineral, the reference mineral is as hard as or harder than your mineral.

Special Properties

All minerals exhibit the properties that were described earlier in this section. However, a few minerals have some additional, special properties that can help identify those minerals. For example, the mineral magnetite is a natural magnet. The mineral calcite is usually white in ordinary light, but in ultraviolet light, it often appears red. Another special property of calcite is shown below.

A clear piece of calcite placed over an image will cause a double image.

Why It Matters

Made from Minerals

SOCIETY AND TECHNOLOGY

Many minerals contain useful substances. Rutile and several other minerals contain the metal titanium. Titanium can resist corrosion and is about as strong as steel, but it is 47% lighter than steel. These properties make titanium very valuable.

Devices for Doctors

Surgical procedures like joint replacements require metal implantations. Titanium is used because it can resist body fluid corrosion and its low density and elasticity is similar to human bone.

Marvels for Mechanics

Motorcycle exhaust pipes are often made out of titanium, which dissipates heat better than stainless steel.

An Aid to Architects

Titanium doesn't just serve practical purposes. Architect Frank Gehry used titanium panels to cover the outside of the Guggenheim Museum in Bilbao, Spain. He chose titanium because of its luster.

Extend

Inquiry

17 Infer How do you think the density of titanium-containing minerals would compare to the density of minerals used to make steel? Explain.

18 List Research some other products made from minerals. Make a list summarizing your research.

19 Determine Choose one of the products you researched. How do the properties of the minerals used to make the product contribute to the product's characteristics or usefulness?

Visual Summary

To complete this summary, fill in the blanks with the correct words or phrase. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Minerals make up Earth's crust.

20 A mineral:

- has a definite chemical composition
- is a solid
- is usually inorganic
- is formed in nature
- _____

Minerals are classified by composition.

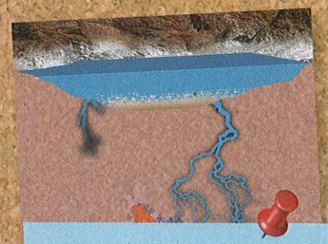
21 Minerals are classified in two groups as:

Quartz, SiO_2

Calcite, $CaCO_3$

_____ _____

Minerals



Minerals form by natural processes.

22 Minerals form by:

- metamorphism
- the cooling of magma and lava
- _____

Minerals are identified by their properties.

23 Properties used to identify minerals include:

- color and luster
- _____
- cleavage or fracture
- density and hardness
- special properties

Answers: 20 has a crystalline structure; 21 silicates (left), nonsilicates (right); 22 precipitating from solutions; 23 streak

24 Apply Ice (H_2O) is a mineral. Classify it as silicate or nonsilicate. List two of its properties.

Lesson Review

Vocabulary

Fill in the blank with the term that best completes the following sentence.

1 The way light bounces off a mineral's surface is described by the mineral's _____

2 The color of a mineral in powdered form is the mineral's _____

3 Each element is made up of only one kind of _____

Key Concepts

4 Explain How could you determine whether an unknown substance is a mineral?

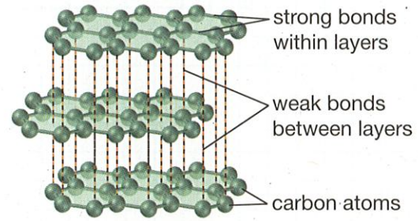
5 Determine If a substance is a mineral, how could you identify what type of mineral it is?

6 Organize In the space below, draw a graphic organizer showing how minerals can be classified. Be sure to include the six main classes of nonsilicate minerals.

Critical Thinking

Use the diagram below to answer question 7.

Carbon Bonds in Graphite



7 Evaluate The diagram above shows the crystal structure of graphite, a mineral made up of carbon atoms that are bonded together in a regular pattern. Do you think graphite would most likely display cleavage or fracture? Explain your answer.

8 Infer How do you think the hardness and density of a mineral that formed through metamorphism would compare to a mineral that formed through evaporation? Explain.