



Minerals

chapter preview

sections

1 Minerals

Lab Crystal Formation

2 Mineral Identification

3 Uses of Minerals

Lab Mineral Identification



Virtual Lab How can minerals be defined by their properties?

Nature's Beautiful Creation

Although cut by gemologists to enhance their beauty, these gorgeous diamonds formed naturally—deep within Earth. One requirement for a substance to be a mineral is that it must occur in nature. Human-made diamonds serve their purpose in industry but are not considered minerals.

Science Journal Write two questions you would ask a gemologist about the minerals that he or she works with.

Start-Up Activities



Distinguish Rocks from Minerals

When examining rocks, you'll notice that many of them are made of more than one material. Some rocks are made of many different crystals of mostly the same mineral. A mineral, however, will appear more like a pure substance and will tend to look the same throughout. Can you tell a rock from a mineral?

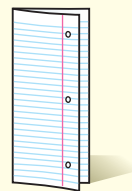


1. Use a magnifying lens to observe a quartz crystal, salt grains, and samples of sandstone, granite, calcite, mica, and schist (SHIHST).
2. Draw a sketch of each sample.
3. Infer which samples are made of one type of material and should be classified as minerals.
4. Infer which samples should be classified as rocks.
5. **Think Critically** In your Science Journal, compile a list of descriptions for the minerals you examined and a second list of descriptions for the rocks. Compare and contrast your observations of minerals and rocks.

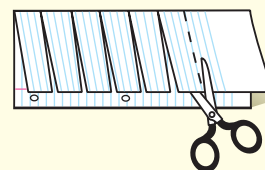
FOLDABLES™ Study Organizer

Minerals Make the following Foldable to help you better understand minerals.

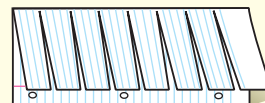
- STEP 1** Fold a vertical sheet of notebook paper from side to side.



- STEP 2** Cut along every third line of only the top layer to form tabs.



- STEP 3** Label each tab with a question.



Ask Questions Before you read the chapter, write questions you have about minerals on the front of the tabs. As you read the chapter, add more questions and write answers under the appropriate tabs.



Preview this chapter's content and activities at green.msscience.com



Minerals

as you read

What You'll Learn

- **Describe** characteristics that all minerals share.
- **Explain** how minerals form.

Why It's Important

You use minerals and products made from them every day.



Review Vocabulary

atoms: tiny particles that make up matter; composed of protons, electrons, and neutrons

New Vocabulary

- mineral
- crystal
- magma
- silicate

Figure 1 You probably use minerals or materials made from minerals every day without thinking about it.

Infer How many objects in this picture might be made from minerals?



What is a mineral?

How important are minerals to you? Very important? You actually own or encounter many things made from minerals every day. Ceramic, metallic, and even some paper items are examples of products that are derived from or include minerals. **Figure 1** shows just a few of these things. Metal bicycle racks, bricks, and the glass in windows would not exist if it weren't for minerals. A **mineral** is a naturally occurring, inorganic solid with a definite chemical composition and an orderly arrangement of atoms. About 4,000 different minerals are found on Earth, but they all share these four characteristics.

Mineral Characteristics First, all minerals are formed by natural processes. These are processes that occur on or inside Earth with no input from humans. For example, salt formed by the natural evaporation of seawater is the mineral halite, but salt formed by evaporation of saltwater solutions in laboratories is not a mineral. Second, minerals are inorganic. This means that they aren't made by life processes. Third, every mineral is an element or compound with a definite chemical composition. For example, halite's composition, NaCl , gives it a distinctive taste that adds flavor to many foods. Fourth, minerals are crystalline solids. All solids have a definite volume and shape. Gases and liquids like air and water have no definite shape, and they aren't crystalline. Only a solid can be a mineral, but not all solids are minerals.

Atom Patterns The word *crystalline* means that atoms are arranged in a pattern that is repeated over and over again. For example, graphite's atoms are arranged in layers. Opal, on the other hand, is not a mineral in the strictest sense because its atoms are not all arranged in a definite, repeating pattern, even though it is a naturally occurring, inorganic solid.



Figure 2 More than 200 years ago, the smooth, flat surfaces on crystals led scientists to infer that minerals had an orderly structure inside.



Even though this rose quartz looks uneven on the outside, its atoms have an orderly arrangement on the inside.

The well-formed crystal shapes exhibited by these clear quartz crystals suggest an orderly structure.

The Structure of Minerals

Do you have a favorite mineral sample or gemstone? If so, perhaps it contains well-formed crystals. A **crystal** is a solid in which the atoms are arranged in orderly, repeating patterns. You can see evidence for this orderly arrangement of atoms when you observe the smooth, flat outside surfaces of crystals. A crystal system is a group of crystals that have similar atomic arrangements and therefore similar external crystal shapes.

 **Reading Check** What is a crystal?

Crystals Not all mineral crystals have smooth surfaces and regular shapes like the clear quartz crystals in **Figure 2**. The rose quartz in the smaller photo of **Figure 2** has atoms arranged in repeating patterns, but you can't see the crystal shape on the outside of the mineral. This is because the rose quartz crystals developed in a tight space, while the clear quartz crystals developed freely in an open space. The six-sided, or hexagonal crystal shape of the clear quartz crystals in **Figure 2**, and other forms of quartz can be seen in some samples of the mineral. **Figure 3** illustrates the six major crystal systems, which classify minerals according to their crystal structures. The hexagonal system to which quartz belongs is one example of a crystal system.

Crystals form by many processes. Next, you'll learn about two of these processes—crystals that form from magma and crystals that form from solutions of salts.

Mini LAB

Inferring Salt's Crystal System

Procedure

1. Use a **magnifying lens** to observe grains of common **table salt** on a dark sheet of **construction paper**. Sketch the shape of a salt grain. **WARNING:** Do not taste or eat mineral samples. Keep hands away from your face.
2. Compare the shapes of the salt crystals with the shapes of crystals shown in **Figure 3**.

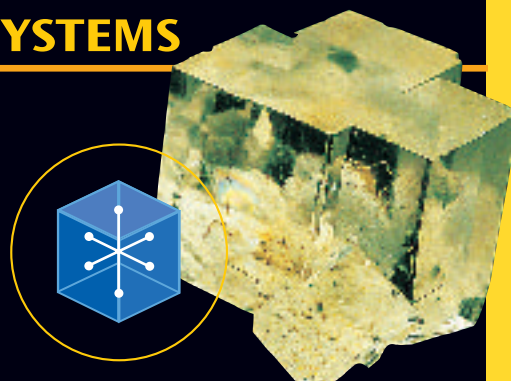
Analysis

1. Which characteristics do all the grains have in common?
2. Research another mineral with the same crystal system as salt. What is this crystal system called?

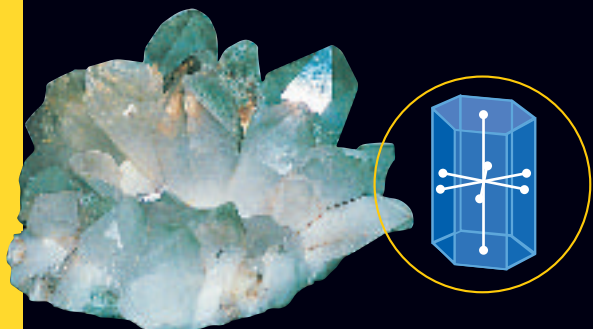


Figure 3

A crystal's shape depends on how its atoms are arranged. Crystal shapes can be organized into groups known as crystal systems—shown here in 3-D with geometric models (in blue). Knowing a mineral's crystal system helps researchers understand its atomic structure and physical properties.



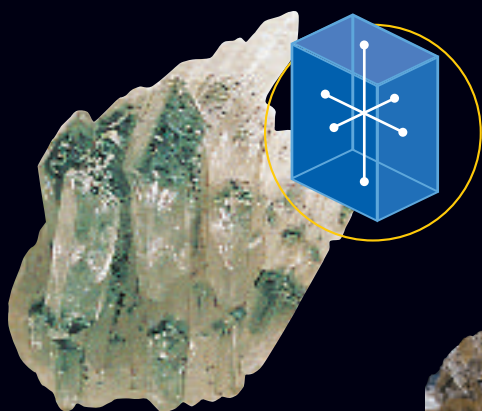
▲ **CUBIC** Fluorite is an example of a mineral that forms cubic crystals. Minerals in the cubic crystal system are equal in size along all three principal dimensions.



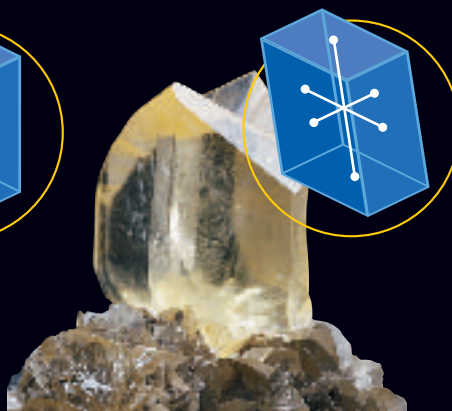
▲ **HEXAGONAL** (hek SA guh nul) In hexagonal crystals, horizontal distances between opposite crystal surfaces are equal. These crystal surfaces intersect to form 60° or 120° angles. The vertical length is longer or shorter than the horizontal lengths.



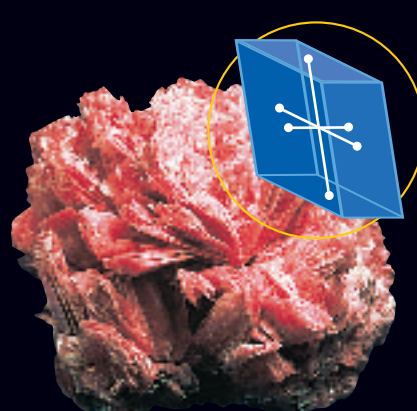
◀ **TETRAGONAL** (te TRA guh nul) Zircon crystals are tetragonal. Tetragonal crystals are much like cubic crystals, except that one of the principal dimensions is longer or shorter than the other two dimensions.



▲ **ORTHORHOMBIC** (awr thuh RAHM bihk) Minerals with orthorhombic structure, such as barite, have dimensions that are unequal in length, resulting in crystals with a brick-like shape.



▲ **MONOCLINIC** (mah nuh KLIH nihk) Minerals in the monoclinic system, such as orthoclase, also exhibit unequal dimensions in their crystal structure. Only one right angle forms where crystal surfaces meet. The other angles are oblique, which means they don't form 90° angles where they intersect.

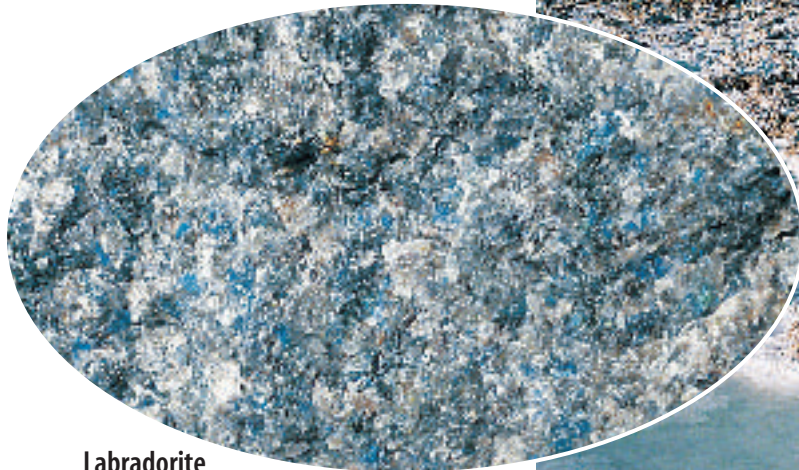


▲ **TRICLINIC** (tri KLIH nihk) The triclinic crystal system includes minerals exhibiting the least symmetry. Triclinic crystals, such as rhodonite (ROH dun ite), are unequal in all dimensions, and all angles where crystal surfaces meet are oblique.



Figure 4 Minerals form by many natural processes.

A This rock formed as magma cooled slowly, allowing large mineral grains to form.



Labradorite



Crystals from Magma Natural processes form minerals in many ways. For example, hot melted rock material, called **magma**, cools when it reaches Earth's surface, or even if it's trapped below the surface. As magma cools, its atoms lose heat energy, move closer together, and begin to combine into compounds. During this process, atoms of the different compounds arrange themselves into orderly, repeating patterns. The type and amount of elements present in a magma partly determine which minerals will form. Also, the size of the crystals that form depends partly on how rapidly the magma cools.

When magma cools slowly, the crystals that form are generally large enough to see with the unaided eye, as shown in **Figure 4A**. This is because the atoms have enough time to move together and form into larger crystals. When magma cools rapidly, the crystals that form will be small. In such cases, you can't easily see individual mineral crystals.

Crystals from Solution Crystals also can form from minerals dissolved in water. When water evaporates, as in a dry climate, ions that are left behind can come together to form crystals like the halite crystals in **Figure 4B**. Or, if too much of a substance is dissolved in water, ions can come together and crystals of that substance can begin to form in the solution. Minerals can form from a solution in this way without the need for evaporation.

B Some minerals form when salt water evaporates, such as these white crystals of halite in Death Valley, California.



Crystal Formation

Evaporites commonly form in dry climates. Research the changes that take place when a saline lake or shallow sea evaporates and halite or gypsum forms.

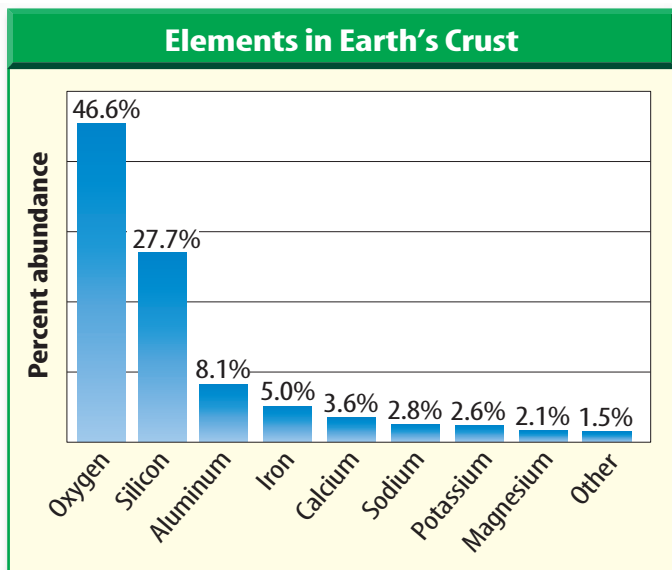


Figure 5 Most of Earth's crust is composed of eight elements.

and oxygen are the two most abundant elements in Earth's crust. These two elements alone combine to form the basic building blocks of most of the minerals in Earth's crust and mantle. Feldspar and quartz, which are silicates, and calcite, which is a carbonate, are examples of common, rock-forming minerals. Other mineral groups also are defined according to their compositions.

Mineral Compositions and Groups

Ninety elements occur naturally in Earth's crust. Approximately 98 percent (by weight) of the crust is made of only eight of these elements, as shown in **Figure 5**. Of the thousands of known minerals, only a few dozen are common, and these are mostly composed of the eight most common elements in Earth's crust.

Most of the common rock-forming minerals belong to a group called the silicates. **Silicates** (SIH luh kayts) are minerals that contain silicon (Si) and oxygen (O) and usually one or more other elements. Silicon

section 1 review

Summary

What is a mineral?

- Many products used by humans are made from minerals.
- Minerals are defined by four main characteristics.

The Structure of Minerals

- The crystal shape of a mineral reflects the way in which its atoms are arranged.
- Minerals are classified according to the types of atoms in their structures and the way that the atoms are arranged.

Mineral Compositions and Groups

- Only eight elements form approximately 98 percent (by weight) of Earth's crust.
- The majority of Earth's crust is composed of silicate minerals.

Self Check

- List** four characteristics that all minerals share.
- Describe** two ways that minerals can form from solution.
- Explain** whether diamonds made in the laboratory are considered to be minerals.
- Describe** how crystals of minerals are classified.
- Think Critically** The mineral dolomite, a rock-forming mineral, contains oxygen, carbon, magnesium, and calcium. Is dolomite a silicate? Explain.

Applying Skills

- Graph** Make a graph of your own design that shows the relative percentages of the eight most common elements in Earth's crust. Then determine the approximate percentage of the crust that is made up of iron and aluminum. If one is available, you may use an electronic spreadsheet program to make your graph and perform the calculation.

Crystal Formation

In this lab, you'll have a chance to learn how crystals form from solutions.

Real-World Question

How do crystals form from solution?

Goals

- **Compare and contrast** the crystals that form from salt and sugar solutions.
- **Observe** crystals and infer how they formed.

Materials

250-mL beakers (2)	cotton string
cardboard	hot plate
large paper clip	magnifying lens
table salt	thermal mitt
flat wooden stick	shallow pan
granulated sugar	spoon

Safety Precautions



WARNING: *Never taste or eat any lab materials.*

Procedure

1. Gently mix separate solutions of salt in water and sugar in water in the two beakers. Keep stirring the solutions as you add salt or sugar to the water. Stop mixing when no more salt or sugar will dissolve in the solutions. Label each beaker.
2. Place the sugar solution beaker on a hot plate. Use the hot plate to heat the sugar solution gently. **WARNING:** *Do not touch the hot beaker without protecting your hands.*
3. Tie one end of the thread to the middle of the wooden stick. Tie a large paper clip to the free end of the string for weight. Place the stick across the opening of the sugar beaker



so the thread dangles in the sugar solution.

4. Remove the beaker from the hot plate and cover it with cardboard. Place it in a location where it won't be disturbed.
5. Pour a thin layer of the salt solution into the shallow pan.
6. Leave the beaker and the shallow pan undisturbed for at least one week.
7. After one week, examine each solution with a magnifying lens to see whether crystals have formed.

Conclude and Apply

1. **Compare and contrast** the crystals that formed from the salt and the sugar solutions. How do they compare with samples of table salt and sugar?
2. **Describe** what happened to the saltwater solution in the shallow pan.
3. Did this same process occur in the sugar solution? Explain.

Communicating Your Data

Make a poster that describes your methods of growing salt and sugar crystals. Present your results to your class.



Mineral Identification

as you read

What You'll Learn

- **Describe** physical properties used to identify minerals.
- **Identify** minerals using physical properties such as hardness and streak.

Why It's Important

Identifying minerals helps you recognize valuable mineral resources.

Review Vocabulary

physical property: any characteristic of a material that you can observe without changing the identity of the material

New Vocabulary

- hardness
- luster
- specific gravity
- streak
- cleavage
- fracture

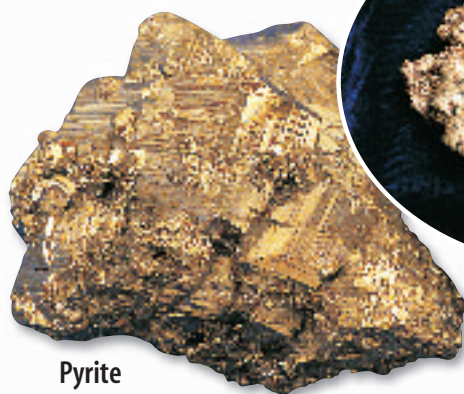
Physical Properties

Why can you recognize a classmate when you see him or her in a crowd away from school? A person's height or the shape of his or her face helps you tell that person from the rest of your class. Height and facial shape are two properties unique to individuals. Individual minerals also have unique properties that distinguish them.

Mineral Appearance Just like height and facial characteristics help you recognize someone, mineral properties can help you recognize and distinguish minerals. Color and appearance are two obvious clues that can be used to identify minerals.

However, these clues alone aren't enough to recognize most minerals. The minerals pyrite and gold are gold in color and can appear similar, as shown in **Figure 6**. As a matter of fact, pyrite often is called fool's gold. Gold is worth a lot of money, whereas pyrite has little value. You need to look at other properties of minerals to tell them apart. Some other properties to study include how hard a mineral is, how it breaks, and its color when crushed into a powder. Every property you observe in a mineral is a clue to its identity.

Figure 6 The general appearance of a mineral often is not enough to identify it.



Pyrite



Gold




Azurite

Using only color, observers can be fooled when trying to distinguish between pyrite and gold.

The mineral azurite is identified readily by its striking blue color.



Hardness A measure of how easily a mineral can be scratched is its **hardness**. The mineral talc is so soft you can scratch it loose with your fingernail. Talcum powder is made from this soft mineral. Diamonds, on the other hand, are the hardest mineral. Some diamonds are used as cutting tools, as shown in **Figure 7**. A diamond can be scratched only by another diamond. Diamonds can be broken, however.

 **Reading Check** Why is hardness sometimes referred to as scratchability?

Sometimes the concept of hardness is confused with whether or not a mineral will break. It is important to understand that even though a diamond is extremely hard, it can shatter if given a hard enough blow in the right direction along the crystal.

Mohs Scale In 1824, the Austrian scientist Friedrich Mohs developed a list of common minerals to compare their hardnesses. This list is called Mohs scale of hardness, as seen in **Table 1**. The scale lists the hardness of ten minerals. Talc, the softest mineral, has a hardness value of one, and diamond, the hardest mineral, has a value of ten.

Here's how the scale works. Imagine that you have a clear or whitish-colored mineral that you know is either fluorite or quartz. You try to scratch it with your fingernail and then with an iron nail. You can't scratch it with your fingernail but you can scratch it with the iron nail. Because the hardness of your fingernail is 2.5 and that of the iron nail is 4.5, you can determine the unknown mineral's hardness to be somewhere around 3 or 4. Because it is known that quartz has a hardness of 7 and fluorite has a hardness of 4, the mystery mineral must be fluorite.

Some minerals have a hardness range rather than a single hardness value. This is because atoms are arranged differently in different directions in their crystal structures.



Figure 7 Some saw blades have diamonds embedded in them to help slice through materials, such as this limestone. Blades are kept cool by running water over them.

Table 1 Mineral Hardness		
Mohs Scale	Hardness	Hardness of Common Objects
Talc (softest)	1	
Gypsum	2	fingernail (2.5)
Calcite	3	piece of copper (2.5 to 3.0)
Fluorite	4	iron nail (4.5)
Apatite	5	glass (5.5)
Feldspar	6	steel file (6.5)
Quartz	7	streak plate (7.0)
Topaz	8	
Corundum	9	
Diamond (hardest)	10	





Figure 8 Luster is an important physical property that is used to distinguish minerals. Graphite has a metallic luster. Fluorite has a nonmetallic, glassy luster.

Luster The way a mineral reflects light is known as **luster**. Luster can be metallic or nonmetallic. Minerals with a metallic luster, like the graphite shown in **Figure 8**, shine like metal. Metallic luster can be compared to the shine of a metal belt buckle, the shiny chrome trim on some cars, or the shine of metallic cooking utensils. When a mineral does not shine like metal, its luster is nonmetallic. Examples of terms for nonmetallic luster include dull, pearly, silky, and glassy. Common examples of minerals with glassy luster are quartz, calcite, halite, and fluorite.

Specific Gravity Minerals also can be distinguished by comparing the weights of equal-sized samples. The **specific gravity** of a mineral is the ratio of its weight compared with the weight of an equal volume of water. Like hardness, specific gravity is expressed as a number. If you were to research the specific gravities of gold and pyrite, you'd find that gold's specific gravity is about 19, and pyrite's is 5. This means that gold is about 19 times heavier than water and pyrite is 5 times heavier than water. You could experience this by comparing equal-sized samples of gold and pyrite in your hands—the pyrite would feel much lighter. The term *heft* is sometimes used to describe how heavy a mineral sample feels.

Applying Science

How can you identify minerals?

Properties of Minerals		
Mineral	Hardness	Streak
Copper	2.5–3	copper-red
Galena	2.5	dark gray
Gold	2.5–3	yellow
Hematite	5.5–6.5	red to brown
Magnetite	6–6.5	black
Silver	2.5–3	silver-white

You have learned that minerals are identified by their physical properties, such as streak, hardness, cleavage, and color. Use your knowledge of mineral properties and your ability to read a table to solve the following problems.

Identifying the Problem

The table includes hardnesses and streak colors for several minerals. How can you use these data to distinguish minerals?

Solving the Problem

1. What test would you perform to distinguish hematite from copper? How would you carry out this test?
2. How could you distinguish copper from galena? What tool would you use?
3. What would you do if two minerals had the same hardness and the same streak color?



Streak When a mineral is rubbed across a piece of unglazed porcelain tile, as in **Figure 9**, a streak of powdered mineral is left behind. **Streak** is the color of a mineral when it is in a powdered form. The streak test works only for minerals that are softer than the streak plate. Gold and pyrite can be distinguished by a streak test. Gold has a yellow streak and pyrite has a greenish-black or brownish-black streak.

Some soft minerals will leave a streak even on paper. The last time you used a pencil to write on paper, you left a streak of the mineral graphite. One reason that graphite is used in pencil lead is because it is soft enough to leave a streak on paper.



Reading Check

Why do gold and pyrite leave a streak, but quartz does not?

Cleavage and Fracture The way a mineral breaks is another clue to its identity. Minerals that break along smooth, flat surfaces have **cleavage** (KLEE vihj). Cleavage, like hardness, is determined partly by the arrangement of the mineral's atoms. Mica is a mineral that has one perfect cleavage. **Figure 10** shows how mica breaks along smooth, flat planes. If you were to take a layer cake and separate its layers, you would show that the cake has cleavage. Not all minerals have cleavage. Minerals that break with uneven, rough, or jagged surfaces have **fracture**. Quartz is a mineral with fracture. If you were to grab a chunk out of the side of that cake, it would be like breaking a mineral that has fracture.



Figure 9 Streak is more useful for mineral identification than is mineral color. Hematite, for example, can be dark red, gray, or silver in color. However, its streak is always dark reddish-brown.

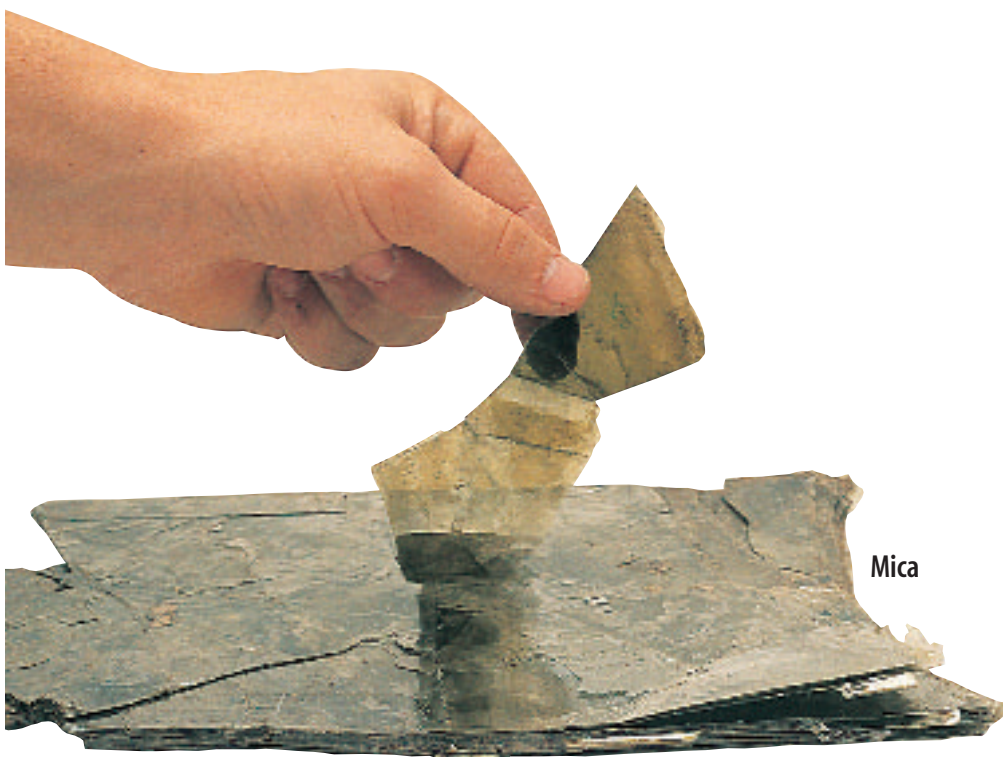


Figure 10 Weak or fewer bonds within the structures of mica and halite allow them to be broken along smooth, flat cleavage planes. **Infer** If you broke quartz, would it look the same?



Mini LAB

Observing Mineral Properties

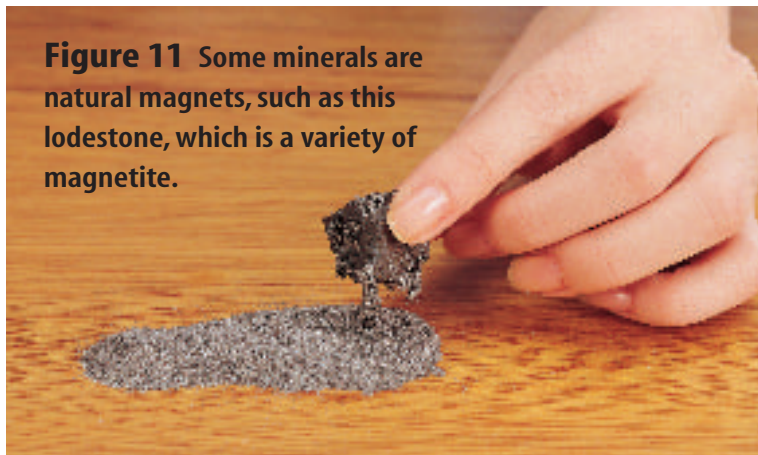
Procedure

1. Obtain samples of some of the following clear minerals: **gypsum**, **muscovite mica**, **halite**, and **calcite**.
2. Place each sample over the print on this page and observe the letters.

Analysis

1. Which mineral can be identified by observing the print's double image?
2. What other special property is used to identify this mineral?

Figure 11 Some minerals are natural magnets, such as this lodestone, which is a variety of magnetite.



Other Properties Some minerals have unique properties. Magnetite, as you can guess by its name, is attracted to magnets. Lodestone, a form of magnetite, will pick up iron filings like a magnet, as shown in **Figure 11**. Light forms two separate rays when it passes through calcite, causing you to see a double image when viewed through transparent specimens. Calcite also can be identified because it fizzes when hydrochloric acid is put on it.

Now you know that you sometimes need more information than color and appearance to identify a mineral. You also might need to test its streak, hardness, luster, and cleavage or fracture. Although the overall appearance of a mineral can be different from sample to sample, its physical properties remain the same.

section 2 review

Summary

Physical Properties

- Minerals are identified by observing their physical properties.
- Hardness is a measure of how easily a mineral can be scratched.
- Luster describes how a mineral reflects light.
- Specific gravity is the ratio of the weight of a mineral sample compared to the weight of an equal volume of water.
- Streak is the color of a powdered mineral.
- Minerals with cleavage break along smooth, flat surfaces in one or more directions.
- Fracture describes any uneven manner in which a mineral breaks.
- Some minerals react readily with acid, form a double image, or are magnetic.

Self Check

1. **Compare and contrast** a mineral fragment that has one cleavage direction with one that has only fracture.
2. **Explain** how an unglazed porcelain tile can be used to identify a mineral.
3. **Explain** why streak often is more useful for mineral identification than color.
4. **Determine** What hardness does a mineral have if it does not scratch glass but it scratches an iron nail?
5. **Think Critically** What does the presence of cleavage planes within a mineral tell you about the chemical bonds that hold the mineral together?

Applying Skills

6. **Draw Conclusions** A large piece of the mineral halite is broken repeatedly into several perfect cubes. How can this be explained?

Uses of Minerals

Gems

Walking past the window of a jewelry store, you notice a large selection of beautiful jewelry—a watch sparkling with diamonds, a necklace holding a brilliant red ruby, and a gold ring. For thousands of years, people have worn and prized minerals in their jewelry. What makes some minerals special? What unusual properties do they have that make them so valuable?

Properties of Gems As you can see in **Figure 12**, **gems** or gemstones are highly prized minerals because they are rare and beautiful. Most gems are special varieties of a particular mineral. They are clearer, brighter, or more colorful than common samples of that mineral. The difference between a gem and the common form of the same mineral can be slight. Amethyst is a gem form of quartz that contains just traces of iron in its structure. This small amount of iron gives amethyst a desirable purple color. Sometimes a gem has a crystal structure that allows it to be cut and polished to a higher quality than that of a non-gem mineral. **Table 2** lists popular gems and some locations where they have been collected.

as you read

What You'll Learn

- **Describe** characteristics of gems that make them more valuable than other minerals.
- **Identify** useful elements that are contained in minerals.

Why It's Important

Minerals are necessary materials for decorative items and many manufactured products.

Review Vocabulary





metal: element that typically is a shiny, malleable solid that conducts heat and electricity well

New Vocabulary

- gem
- ore



Figure 12 It is easy to see why gems are prized for their beauty and rarity. Shown here is The Imperial State Crown, made for Queen Victoria of England in 1838. It contains thousands of jewels, including diamonds, rubies, sapphires, and emeralds.

Table 2 Minerals and Their Gems			
Fun Facts	Mineral	Gem Example	Some Important Locations
Beryl is named for the element beryllium, which it contains. Some crystals reach several meters in length.	Beryl 	Emerald 	Colombia, Brazil, South Africa, North Carolina
A red spinel in the British crown jewels has a mass of 352 carats. A carat is 0.2 g.	Spinel 	Ruby spinel 	Sri Lanka, Thailand, Myanmar (Burma)
Purplish-blue examples of zoisite were discovered in 1967 near Arusha, Tanzania.	Zoisite 	Tanzanite 	Tanzania
The most valuable examples are yellow, pink, and blue varieties.	Topaz (uncut) 	Topaz (gem) 	Siberia, Germany, Japan, Mexico, Brazil, Colorado, Utah, Texas, California, Maine, Virginia, South Carolina

Fun Facts	Mineral	Gem Example	Some Important Locations
<p>Olivine composes a large part of Earth's upper mantle. It is also present in moon rocks.</p>	<p>Olivine</p> 	<p>Peridot</p> 	<p>Myanmar (Burma), Zebirget (Saint John's Island, located in the Red Sea), Arizona, New Mexico</p>
<p>Garnet is a common mineral found in a wide variety of rock types. The red color of the variety almandine is caused by iron in its crystal structure.</p>	<p>Garnet</p> 	<p>Almandine</p> 	<p>Ural Mountains, Italy, Madagascar, Czech Republic, India, Sri Lanka, Brazil, North Carolina, Arizona, New Mexico</p>
<p>Quartz makes up about 30 percent of Earth's continental crust.</p>	<p>Quartz</p> 	<p>Amethyst</p> 	<p>Colorless varieties in Hot Springs, Arkansas; Amethyst in Brazil, Uruguay, Madagascar, Montana, North Carolina, California, Maine</p>
<p>The blue color of sapphire is caused by iron or titanium in corundum. Chromium in corundum produces the red color of ruby.</p>	<p>Corundum</p> 	<p>Blue sapphire</p> 	<p>Thailand, Cambodia, Sri Lanka, Kashmir</p>



Topic: Gemstone Data

Visit green.mssscience.com for Web links to information about gems at the Smithsonian Museum of Natural History.

Activity List three important examples of gems other than those described on this page. Prepare a data table with the heads *Gem Name/Type*, *Weight (carats/grams)*, *Mineral*, and *Location*. Fill in the table entries for the gemstones you selected.

Figure 13 These gems are among the most famous examples of precious stones.

A The Great Star of Africa is part of a sceptre in the collection of British crown jewels.



B Beginning in 1668, the Hope diamond was part of the French crown jewels. Then known as the French Blue, it was stolen in 1792 and later surfaced in London, England in 1812.



Important Gems All gems are prized, but some are truly spectacular and have played an important role in history. For example, the Cullinan diamond, found in South Africa in 1905, was the largest uncut diamond ever discovered. Its mass was 3,106.75 carats (about 621 g). The Cullinan diamond was cut into 9 main stones and 96 smaller ones. The largest of these is called the Cullinan 1 or Great Star of Africa. Its mass is 530.20 carats (about 106 g), and it is now part of the British monarchy's crown jewels, shown in **Figure 13A**.

Another well-known diamond is the blue Hope diamond, shown in **Figure 13B**. This is perhaps the most notorious of all diamonds. It was purchased by Henry Philip Hope around 1830, after whom it is named. Because his entire family as well as a later owner suffered misfortune, the Hope diamond has gained a reputation for bringing its owner bad luck. The Hope diamond's mass is 45.52 carats (about 9 g). Currently it is displayed in the Smithsonian Institution in Washington, D.C.

Useful Gems In addition to their beauty, some gems serve useful purposes. You learned earlier that diamonds have a hardness of 10 on Mohs scale. They can scratch almost any material—a property that makes them useful as industrial abrasives and cutting tools. Other useful gems include rubies, which are used to produce specific types of laser light. Quartz crystals are used in electronics and as timepieces. When subjected to an electric field, quartz vibrates steadily, which helps control frequencies in electronic devices and allows for accurate timekeeping.

Most industrial diamonds and other gems are synthetic, which means that humans make them. However, the study of natural gems led to their synthesis, allowing the synthetic varieties to be used by humans readily.



Figure 14 Bauxite, an ore of aluminum, is processed to make pure aluminum metal for useful products.



Bauxite

Useful Elements in Minerals

Gemstones are perhaps the best-known use of minerals, but they are not the most important. Look around your home. How many things made from minerals can you name? Can you find anything made from iron?

Ores Iron, used in everything from frying pans to ships, is obtained from its ore, hematite. A mineral or rock is an **ore** if it contains a useful substance that can be mined at a profit. Magnetite is another mineral that contains iron.

 **Reading Check** *When is a mineral also an ore?*



Aluminum sometimes is refined, or purified, from the ore bauxite, shown in **Figure 14**. In the process of refining aluminum, aluminum oxide powder is separated from unwanted materials that are present in the original bauxite. After this, the aluminum oxide powder is converted to molten aluminum by a process called smelting.

During smelting, a substance is melted to separate it from any unwanted materials that may remain. Aluminum can be made into useful products like bicycles, soft-drink cans, foil, and lightweight parts for airplanes and cars. The plane flown by the Wright brothers during the first flight at Kitty Hawk had an engine made partly of aluminum.



Historical Mineralogy An early scientific description of minerals was published by Georgius Agricola in 1556. Use print and online resources to research the mining techniques discussed by Agricola in his work *De Re Metallica*.



Figure 15 The mineral sphalerite (greenish when nearly pure) is an important source of zinc. Iron often is coated with zinc to prevent rust in a process called galvanization.



Vein Minerals Under certain conditions, metallic elements can dissolve in fluids. These fluids then travel through weaknesses in rocks and form mineral deposits. Weaknesses in rocks include natural fractures or cracks, faults, and surfaces between layered rock formations. Mineral deposits left behind that fill in the open spaces created by the weaknesses are called vein mineral deposits.



Reading Check

How do fluids move through rocks?

Sometimes vein mineral deposits fill in the empty spaces after rocks collapse. An example of a mineral that can form in this way is shown in **Figure 15**. This is the shiny mineral sphalerite, a source of the element zinc, which is used in batteries. Sphalerite sometimes fills spaces in collapsed limestone.

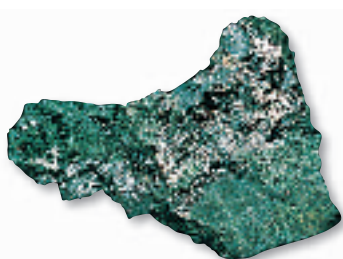
Minerals Containing Titanium You might own golf clubs with titanium shafts or a racing bicycle containing titanium. Perhaps you know someone who has a titanium hip or knee replacement. Titanium is a durable, lightweight, metallic element derived from minerals that contain this metal in their crystal structures. Two minerals that are sources of the element

titanium are ilmenite (IHL muh nite) and rutile (rew TEEL), shown in **Figure 16**. Ilmenite and rutile are common in rocks that form when magma cools and solidifies. They also occur as vein mineral deposits and in beach sands.

Figure 16 Rutile and ilmenite are common ore minerals of the element titanium.



Rutile



Ilmenite



Uses for Titanium Titanium is used in automobile body parts, such as connecting rods, valves, and suspension springs. Low density and durability make it useful in the manufacture of aircraft, eyeglass frames, and sports equipment such as tennis rackets and bicycles. Wheelchairs used by people who want to race or play basketball often are made from titanium, as shown in **Figure 17**. Titanium is one of many examples of useful materials that come from minerals and that enrich humans' lives.

Figure 17 Wheelchairs used for racing and playing basketball often have parts made from titanium.

section 3 review

Summary

Gems

- Gems are highly prized mineral specimens often used as decorative pieces in jewelry or other items.
- Some gems, especially synthetic ones, have industrial uses.

Useful Elements in Minerals

- Economically important quantities of useful elements or compounds are present in ores.
- Ores generally must be processed to extract the desired material.
- Iron, aluminum, zinc, and titanium are common metals that are extracted from minerals.

Self Check

1. **Explain** why the Cullinan diamond is an important gem.
2. **Identify** Examine **Table 2**. What do rubies and sapphires have in common?
3. **Describe** how vein minerals form.
4. **Explain** why bauxite is considered to be a useful rock.
5. **Think Critically** Titanium is nontoxic. Why is this important in the manufacture of artificial body parts?

Applying Skills

6. **Use Percentages** Earth's average continental crust contains 5 percent iron and 0.007 percent zinc. How many times more iron than zinc is present in average continental crust?

Mineral Identification

Goals

- **Hypothesize** which properties of each mineral are most useful for identification purposes.
- **Test** your hypothesis as you attempt to identify unknown mineral samples.

Materials

mineral samples
 magnifying lens
 pan balance
 graduated cylinder
 water
 piece of copper
 *copper penny
 glass plate
 small iron nail
 steel file
 streak plate
 5% HCl with dropper
 Mohs scale of hardness
 Minerals Appendix
 *minerals field guide
 safety goggles
 *Alternate materials

Safety Precautions



WARNING: If an HCl spill occurs, notify your teacher and rinse with cool water until you are told to stop. Do not taste, eat, or drink any lab materials.

Real-World Question

Although certain minerals can be identified by observing only one property, others require testing several properties to identify them. How can you identify unknown minerals?

Procedure

1. Copy the data table into your Science Journal. Obtain a set of unknown minerals.
2. Observe a numbered mineral specimen carefully. Write a star in the table entry that represents what you hypothesize is an important physical property. Choose one or two properties that you think will help most in identifying the sample.
3. Perform tests to observe your chosen properties first.
 - a. To estimate hardness:
 - Rub the sample firmly against objects of known hardness and observe whether it leaves a scratch on the objects.
 - Estimate a hardness range based on which items the mineral scratches.
 - b. To estimate specific gravity: Perform a density measurement.
 - Use the pan balance to determine the sample's mass, in grams.



Using Scientific Methods

- Measure its volume using a graduated cylinder partially filled with water. The amount of water displaced by the immersed sample, in mL, is an estimate of its volume in cm^3 .
 - Divide mass by volume to determine density. This number, without units, is comparable to specific gravity.
4. With the help of the Mineral Appendix or a field guide, attempt to identify the sample using the properties from step 2. Perform more physical property observations until you can identify the sample. Repeat steps 2 through 4 for each unknown.



Physical Properties of Minerals

Sample Number	Hardness	Cleavage or Fracture	Color	Specific Gravity	Luster and Streak	Crystal Shape	Other Properties	Mineral Name
1								
2			Do not write in this book.					
etc.								

Analyze Your Data

- Which properties were most useful in identifying your samples? Which properties were least useful?
- Compare** the properties that worked best for you with those that worked best for other students.

Conclude and Apply

- Determine** two properties that distinguish clear, transparent quartz from clear, transparent calcite. Explain your choice of properties.
- Which physical properties would be easiest to determine if you found a mineral specimen in the field?

Communicating Your Data

For three minerals, list physical properties that were important for their identification. For more help, refer to the **Science Skill Handbook**.



Dr. Dorothy Crowfoot Hodgkin

Like X rays, electrons are diffracted by crystalline substances, revealing information about their internal structures and symmetry. This electron diffraction pattern of titanium was obtained with an electron beam focused along a specific direction in the crystal.

Trailblazing scientist and humanitarian

What contributions did Dorothy Crowfoot Hodgkin make to science?

Dr. Hodgkin used a method called X-ray crystallography (kris tuh LAH gruh fee) to figure out the structures of crystalline substances, including vitamin B¹², vitamin D, penicillin, and insulin.

What's X-ray crystallography?

Scientists expose a crystalline sample to X rays. As X rays travel through a crystal, the crystal diffracts, or scatters, the X rays into a regular pattern. Like an individual's fingerprints, each crystalline substance has a unique diffraction pattern.

Crystallography has applications in the life, Earth, and physical

sciences. For example, geologists use X-ray crystallography to identify and study minerals found in rocks.

What were some obstacles Hodgkin overcame?

During the 1930s, there were few women scientists. Hodgkin was not even allowed to attend meetings of the chemistry faculty where she taught because she was a woman. Eventually, she won over her colleagues with her intelligence and tenacity.

How does Hodgkin's research help people today?

Dr. Hodgkin's discovery of the structure of insulin helped scientists learn how to control diabetes, a disease that affects more than 15 million Americans. Diabetics' bodies are unable to process sugar efficiently. Diabetes can be fatal. Fortunately, Dr. Hodgkin's research with insulin has saved many lives.



1910–1994

Research Look in reference books or go to the Glencoe Science Web site for information on how X-ray crystallography is used to study minerals. Write your findings and share them with your class.

Science  **online**

For more information, visit green.msscience.com/time

Reviewing Main Ideas

Section 1 Minerals

1. Much of what you use each day is made at least in some part from minerals.
2. All minerals are formed by natural processes and are inorganic solids with definite chemical compositions and orderly arrangements of atoms.
3. Minerals have crystal structures in one of six major crystal systems.

3. Streak is the color of the powder left by a mineral on an unglazed porcelain tile.
4. Minerals that break along smooth, flat surfaces have cleavage. When minerals break with rough or jagged surfaces, they are displaying fracture.
5. Some minerals have special properties that aid in identifying them. For example, magnetite is identified by its attraction to a magnet.

Section 2 Mineral Identification

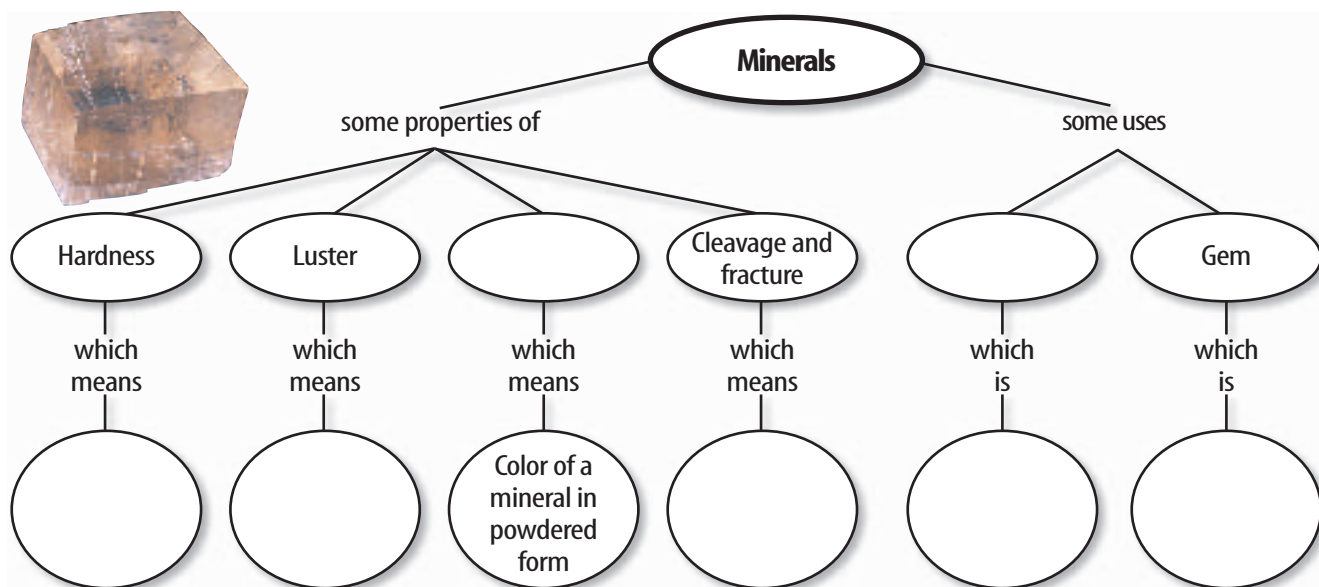
1. Hardness is a measure of how easily a mineral can be scratched.
2. Luster describes how light reflects from a mineral's surface.

Section 3 Uses of Minerals

1. Gems are minerals that are more rare and beautiful than common minerals.
2. Minerals are useful for their physical properties and for the elements they contain.

Visualizing Main Ideas

Copy and complete the following concept map about minerals. Use the following words and phrases: the way a mineral breaks, the way a mineral reflects light, ore, a rare and beautiful mineral, how easily a mineral is scratched, streak, and a useful substance mined for profit.



Using Vocabulary

cleavage p.39	magma p.33
crystal p.31	mineral p.30
fracture p.39	ore p.45
gem p.41	silicate p.34
hardness p.37	specific gravity p.38
luster p.38	streak p.39

Explain the difference between the vocabulary words in each of the following sets.

1. cleavage—fracture
2. crystal—mineral
3. luster—streak
4. magma—crystal
5. hardness—specific gravity
6. ore—mineral
7. crystal—luster
8. mineral—silicate
9. gem—crystal
10. streak—specific gravity

Checking Concepts

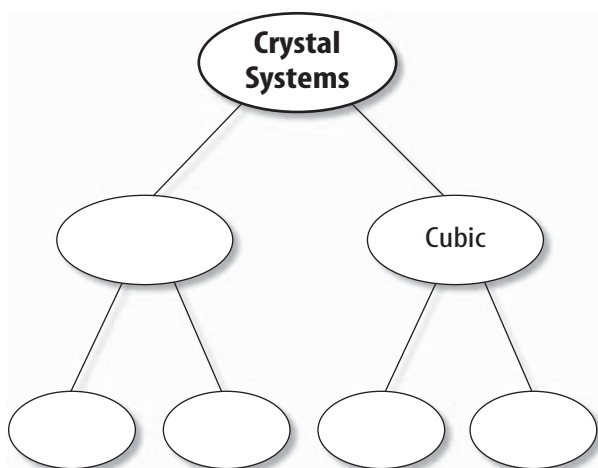
Choose the word or phrase that best answers the question.

11. Which is a characteristic of a mineral?
 - A) It can be a liquid.
 - B) It is organic.
 - C) It has no crystal structure.
 - D) It is inorganic.
12. What must all silicates contain?
 - A) magnesium
 - B) silicon and oxygen
 - C) silicon and aluminum
 - D) oxygen and carbon
13. What is the measure of how easily a mineral can be scratched?
 - A) luster
 - B) hardness
 - C) cleavage
 - D) fracture
14. Examine the photo of quartz above. In what way does quartz break?
 - A) cleavage
 - B) fracture
 - C) luster
 - D) flat planes
15. Which of the following must crystalline solids have?
 - A) carbonates
 - B) cubic structures
 - C) orderly arrangement of atoms
 - D) cleavage
16. What is the color of a powdered mineral formed when rubbing it against an unglazed porcelain tile?
 - A) luster
 - B) density
 - C) hardness
 - D) streak
17. Which is hardest on Mohs scale?
 - A) talc
 - B) quartz
 - C) diamond
 - D) feldspar



Thinking Critically

- 18. Classify** Water is an inorganic substance that is formed by natural processes on Earth. It has a unique composition. Sometimes water is a mineral and other times it is not. Explain.
- 19. Determine** how many sides a perfect salt crystal has.
- 20. Apply** Suppose you let a sugar solution evaporate, leaving sugar crystals behind. Are these crystals minerals? Explain.
- 21. Predict** Will a diamond leave a streak on a streak plate? Explain.
- 22. Collect Data** Make an outline of how at least seven physical properties can be used to identify unknown minerals.
- 23. Explain** how you would use **Table 1** to determine the hardness of any mineral.
- 24. Concept Map** Copy and complete the concept map below, which includes two crystal systems and two examples from each system. Use the following words and phrases: *hexagonal*, *corundum*, *halite*, *fluorite*, and *quartz*.



Performance Activities

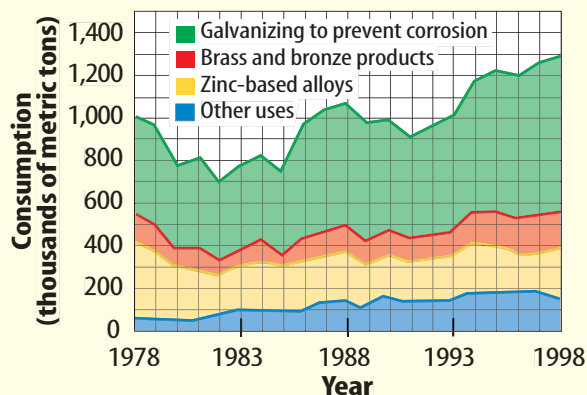
- 25. Display** Make a display that shows the six crystal systems of minerals. Research the crystal systems of minerals and give three examples for each crystal system. Indicate whether any of the minerals are found in your state. Describe any important uses of these minerals. Present your display to the class.

Applying Math

- 26. Mineral Volume** Recall that $1 \text{ mL} = 1 \text{ cm}^3$. Suppose that the volume of water in a graduated cylinder is 107.5 mL. A specimen of quartz, tied to a piece of string, is immersed in the water. The new water level reads 186 mL. What is the volume, in cm^3 , of the piece of quartz?

Use the graph below to answer questions 27 and 28.

U.S. Slab Zinc Consumption 1978–1998

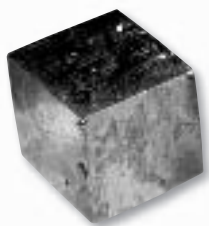


- 27. Zinc Use** According to the graph above, what was the main use of zinc consumed in the United States between 1978 and 1998?
- 28. Metal Products** According to the graph, approximately how many thousand metric tons of zinc were used to make brass and bronze products in 1998?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the photo below to answer question 1.



- To which crystal system does the crystal shown above belong?
 - hexagonal
 - cubic
 - triclinic
 - monoclinic
- Which of the following is a common rock-forming mineral?
 - azurite
 - gold
 - quartz
 - diamond
- Which term refers to the resistance of a mineral to scratching?
 - hardness
 - specific gravity
 - luster
 - fracture
- Which is a special property of the mineral magnetite?
 - attracted by a magnet
 - fizzes with dilute hydrochloric acid
 - forms a double image
 - has a salty taste
- Which causes some minerals to break along smooth, flat surfaces?
 - streak
 - cleavage
 - luster
 - fracture

Test-Taking Tip

If you are taking a timed test, keep track of time during the test. If you find that you're spending too much time on a multiple-choice question, mark your best guess and move on.

- Which of these forms in cracks or along faults?
 - bauxite
 - silicates
 - vein minerals
 - rock-forming minerals
- Which is the most abundant element in Earth's crust?
 - silicon
 - manganese
 - iron
 - oxygen

Use the table below to answer questions 8–10.

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

- Which mineral in the table is softest?
 - diamond
 - feldspar
 - talc
 - gypsum
- Which mineral will scratch feldspar but not topaz?
 - quartz
 - calcite
 - apatite
 - diamond
- After whom is the scale shown above named?
 - Neil Armstrong
 - Friedrich Mohs
 - Alfred Wegener
 - Isaac Newton

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

11. What is the definition of a mineral?
12. Why are gems valuable?
13. Explain the difference between fracture and cleavage.
14. Why is mineral color sometimes not helpful for identifying minerals?

Use the conversion factor and table below to answer questions 15–17.

$$1.0 \text{ carat} = 0.2 \text{ grams}$$

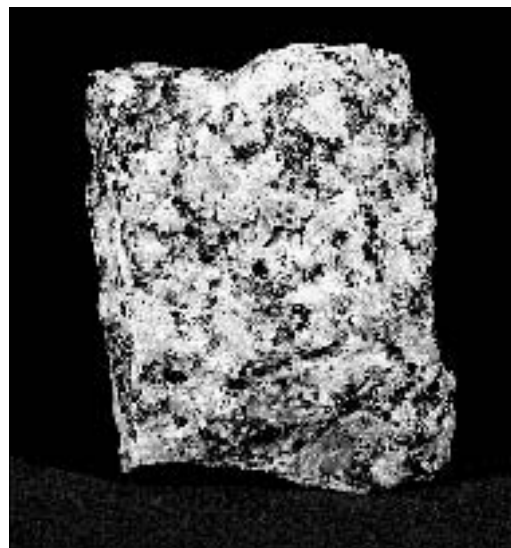
Diamond	Carats	Grams
<i>Uncle Sam</i> : largest diamond found in United States	40.4	?
<i>Punch Jones</i> : second largest U.S. diamond; named after boy who discovered it	?	6.89
<i>Theresa</i> : discovered in Wisconsin in 1888	21.5	4.3
2001 diamond production from western Australia	21,679,930	?

15. How many grams is the *Uncle Sam* diamond?
16. How many carats is the *Punch Jones* diamond?
17. How many grams of diamond were produced in western Australia in 2001?
18. What is the source of most of the diamonds that are used for industrial purposes?
19. Explain how minerals are useful to society. Describe some of their uses.

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the photo below to answer question 20.



20. The mineral crystals in the rock above formed when magma cooled and are visible with the unaided eye. Hypothesize about how fast the magma cooled.
21. What is a crystal system? Why is it useful to classify mineral crystals this way?
22. How can a mineral be identified using its physical properties?
23. What is a crystal? Do all crystals have smooth crystal faces? Explain.
24. Are gases that are given off by volcanoes minerals? Why or why not?
25. What is the most abundant mineral group in Earth's crust? What elements always are found in the minerals included in this group?
26. Several layers are peeled from a piece of muscovite mica? What property of minerals does this illustrate? Describe this property in mica.