Texture Texture describes how a mineral feels to the touch. This, like luster, is subjective. Therefore, texture is often used in combination with other tests to identify a mineral. The texture of a mineral might be described as smooth, rough, ragged, greasy, or soapy. For example, fluorite, shown in **Figure 4.11,** has a smooth texture, while the texture of talc, shown in **Figure 4.6,** is greasy.

■ **Figure 4.11** Textures are interpreted differently by different people. The texture of this fluorite is usually described as smooth.

Density and specific gravity Sometimes, two minerals of the same size have different weights. Differences in weight are the result of differences in density, which is defined as mass per unit of volume. Density is expressed as follows.

$$D = \frac{M}{V}$$

In this equation, D = density, M = mass and V = volume. For example, pyrite has a density of 5.2 g/cm^3, and gold has a density of 19.3 g/cm^3. If you had a sample of gold and a sample of pyrite of the same size, the gold would have greater weight because it is denser.

Density reflects the atomic mass and structure of a mineral. Because density is not dependent on the size or shape of a mineral, it is a useful identification tool. Often, however, differences in density are too small to be distinguished by lifting different minerals. Thus, for accurate mineral identification, density must be measured. The most common measure of density used by geologists is **specific gravity,** which is the ratio of the mass of a substance to the mass of an equal volume of water at 4°C. For example, the specific gravity of pyrite is 5.2. The specific gravity of pure gold is 19.3.

Section 4.1 Assessment

Section Summary

- A mineral is a naturally occurring, inorganic solid with a specific chemical composition and a definite crystalline structure.
- A crystal is a solid in which the atoms are arranged in repeating patterns.
- Minerals form from magma or from supersaturated solutions.
- Minerals can be identified based on their physical and chemical properties.
- The most reliable way to identify a mineral is by using a combination of several tests.

Understand Main Ideas

1. MAIN Idea **List** two reasons why petroleum is not a mineral.
2. **Define** *naturally occurring* in terms of mineral formation.
3. **Contrast** the formation of minerals from magma and their formation from solution.
4. **Differentiate** between subjective and objective mineral properties.

Think Critically

5. **Develop** a plan to test the hardness of a sample of feldspar using the following items: glass plate, copper penny, and streak plate.
6. **Predict** the success of a lab test in which students plan to compare the streak colors of fluorite, quartz, and feldspar.

MATH in Earth Science

7. Calculate the volume of a 5-g sample of pure gold.

Section 4.2

Objectives

- **Identify** different groups of minerals.
- **Illustrate** the silica tetrahedron.
- **Discuss** how minerals are used.

Review Vocabulary

chemical bond: the force that holds two atoms together

New Vocabulary

silicate
tetrahedron
ore
gem

Types of Minerals

MAIN Idea **Minerals are classified based on their chemical properties and characteristics.**

Real-World Reading Link Everything on Earth is classified into various categories. Food, animals, and music are all classified according to certain properties or features. Minerals are no different; they, too, are classified into groups.

Mineral Groups

You have learned that elements combine in many different ways and proportions. One result is the thousands of different minerals present on Earth. In order to study these minerals and understand their properties, geologists have classified them into groups. Each group has a distinct chemical nature and specific characteristics.

Silicates Oxygen is the most abundant element in Earth's crust, followed by silicon. Minerals that contain silicon and oxygen, and usually one or more other elements, are known as **silicates.** Silicates make up approximately 96 percent of the minerals present in Earth's crust. The two most common minerals, feldspar and quartz, are silicates. The basic building block of the silicates is the silica tetrahedron, shown in **Figure 4.12.** A **tetrahedron** (plural, tetrahedra) is a geometric solid having four sides that are equilateral triangles, resembling a pyramid. Recall from Chapter 3 that the electrons in the outermost energy level of an atom are called valence electrons. The number of valence electrons determines the type and number of chemical bonds an atom will form. Because silicon atoms have four valence electrons, silicon has the ability to bond with four oxygen atoms. As shown in **Figure 4.13,** silica tetrahedra can share oxygen atoms. This structure allows tetrahedra to combine in a number of ways, which accounts for the large diversity of structures and properties of silicate minerals.

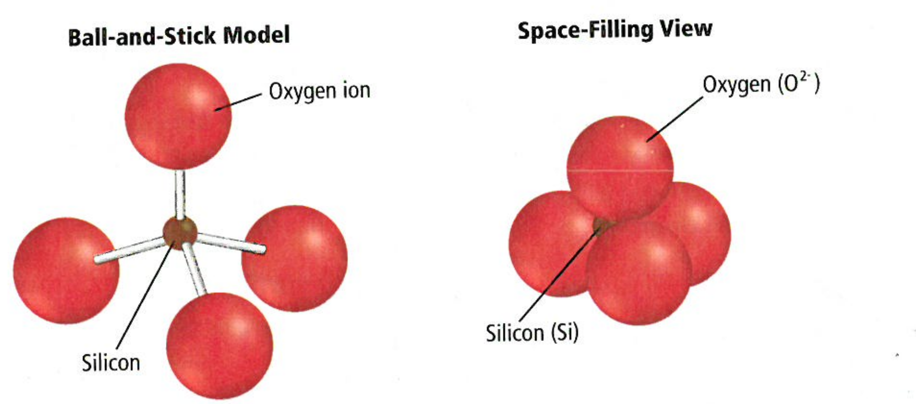
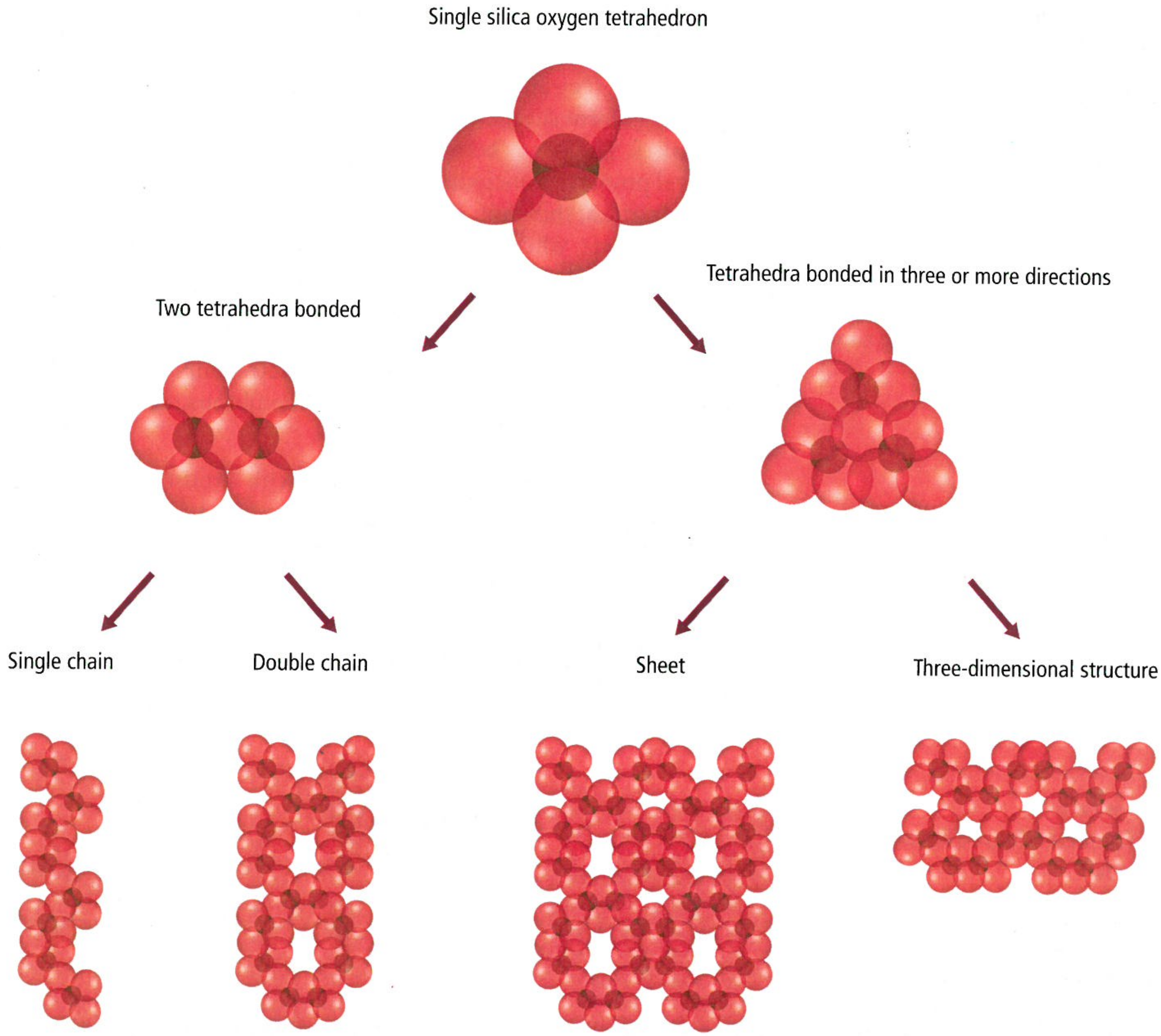


Figure 4.12 The silicate polyatomic ion SiO_4^{2-} forms a tetrahedron in which a central silicon atom is covalently bonded to oxygen ions.
Specify ***How many atoms are in one tetrahedron?***

Visualizing the Silica Tetrahedron

NATIONAL GEOGRAPHIC

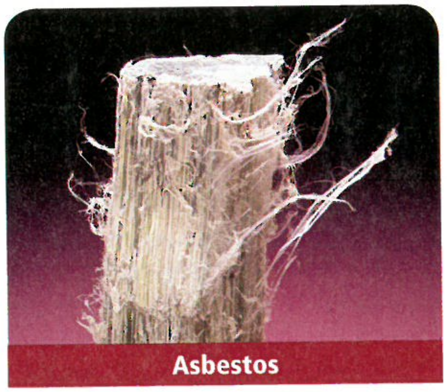
Figure 4.13 The tetrahedron formed by silicates contains four oxygen ions bonded to a central silicon atom. Chains, sheets, and complex structures form as the tetrahedra bond with other tetrahedra. These structures become the numerous silicate minerals that are present on Earth.



Concepts In Motion To explore more about the bonding behavior of the silica tetrahedron, visit glencoe.com.

Earth Science Online

■ **Figure 4.14** The differences in silicate minerals are due to the differences in the arrangement of their silica tetrahedra. Certain types of asbestos consist of weakly bonded double chains of tetrahedra, while mica consists of weakly bonded sheets of tetrahedra.



VOCABULARY
SCIENCE USAGE V. COMMON USAGE

Phyllo

Science usage: the sheets of silica tetrahedra

Common usage: sheets of dough used to make pastries and pies

Individual tetrahedron ions are strongly bonded. They can bond together to form sheets, chains, and complex three-dimensional structures. The bonds between the atoms help determine several mineral properties, including a mineral's cleavage or fracture. For example, mica, shown in **Figure 4.14,** is a sheet silicate, also called a phyllosilicate, where positive potassium or aluminum ions bond the negatively charged sheets of tetrahedra together. Mica separates easily into sheets because the attraction between the tetrahedra and the aluminum or potassium ions is weak. Asbestos, also shown in **Figure 4.14,** consists of double chains of tetrahedra that are weakly bonded together. This results in the fibrous nature shown in **Figure 4.14.**

Carbonates Oxygen combines easily with almost all other elements, and forms other mineral groups, such as carbonates. Carbonates are minerals composed of one or more metallic elements and the carbonate ion CO_3^{2-}. Examples of carbonates are calcite, dolomite, and rhodochrosite. Carbonates are the primary minerals found in rocks such as limestone and marble. Some carbonates have distinctive colorations, such as the colorful varieties of calcite and the pink of rhodochrosite shown in **Figure 4.16.**

■ **Figure 4.15**

Mineral Use Through Time

The value and uses of minerals have changed over time.

10,000 B.C. — 3000 B.C. — 500 B.C.

12,000–9000 B.C. The demand for flint—a hard volcanic glass used for tools—produces the first known long-distance trade route.

3300–3000 B.C. Bronze weapons and tools become common in the Near East as large cities and powerful empires arise.

1200–1000 B.C. In the Near East, bronze becomes scarce and is replaced by iron in tools and weapons.

800 B.C. Diamond use spreads from India to other parts of the world to be used for cutting, engraving, and in ceremonies.

506 B.C. Rome takes over the salt industry at Ostia. The word *salary* comes from *salarium argentums,* the salt rations paid to Roman soldiers.


Calcite


Rhodochrosite

■ **Figure 4.16** Carbonates such as calcite and rhodochrosite occur in distinct colors due to trace elements found in them.

Oxides Oxides are compounds of oxygen and a metal. Hematite (Fe_2O_3) and magnetite (Fe_3O_4) are common iron oxides and good sources of iron. The mineral uraninite (UO_2) is valuable because it is the major source of uranium, which is used to generate nuclear power.

Other groups Other major mineral groups are sulfides, sulfates, halides, and native elements. Sulfides, such as pyrite (FeS_2), are compounds of sulfur and one or more elements. Sulfates, such as anhydrite ($CaSO_4$), are composed of elements with the sulfate ion SO_4^{2-}. Halides, such as halite (NaCl), are made up of chloride or fluoride along with calcium, sodium, or potassium. A native element such as silver (Ag) or copper (Cu), is made up of one element only.

Economic Minerals

Minerals are virtually everywhere. They are used to make computers, cars, televisions, desks, roads, buildings, jewelry, beds, paints, sports equipment, and medicines, in addition to many other things. You can learn about the uses of minerals throughout history by examining **Figure 4.15.**

800–900 Chinese alchemists combine saltpeter with sulfur and carbon to make gunpowder, which is first used for fireworks and later used for weapons.

1546 South American silver mines help establish Spain as a global trading power, supplying silver needed for coinage.

2006 There are 242 uranium-fueled nuclear power plants in operation worldwide with a net capacity of 369.566 GW(e).

A.D. 500 — 1500 — 2000

A.D. 200–400 Iron farming tools and weapons allow people to migrate across Africa clearing and cultivating land for agricultural settlement and driving out hunter-gatherer societies.

1927 The first quartz clock improves timekeeping accuracy. The properties of quartz make it instrumental to the development of radio, radar, and computers.

Concepts In Motion

Interactive Time Line To learn more about these discoveries and others, visit glencoe.com. Earth Science Online

Concepts In Motion
Interactive Table To explore more about major mineral groups, visit glencoe.com.

Table 4.4 Major Mineral Groups

Group	Examples	Economic Use
Silicates	mica (biotite) olivine (Mg_2SiO_4) quartz (SiO_2) vermiculite	furnace windows gem (as peridot) timepieces potting soil additive; swells when wet
Sulfides	pyrite (FeS_2) marcasite (FeS_2) galena (PbS) sphalerite (ZnS)	used to make sulfuric acid; often mistaken for gold (fool's gold) jewelry lead ore zinc ore
Oxides	hematite (Fe_2O_3) corundum (Al_2O_3) uraninite (UO_2) ilmenite ($FeTiO_3$) chromite ($FeCr_2O_4$)	iron ore; red pigment abrasive, gem (as in ruby or sapphire) uranium source titanium source; pigment; replaced lead in paint chromium source, plumbing fixtures, auto accessories
Sulfates	gypsum ($CaSO_4 \cdot 2H_2O$) anhydrite ($CaSO_4$)	plaster, drywall; slows drying in cement plaster; name indicates absence of water
Halides	halite (NaCl) fluorite (CaF_2) sylvite (KCl)	table salt, stock feed, weed killer, food preparation and preservative steel manufacturing, enameling cookware fertilizer
Carbonates	calcite ($CaCO_3$) dolomite ($CaMg(CO_3)_2$)	Portland cement, lime, chalk Portland cement, lime; source of calcium and magnesium in vitamin supplements
Native elements	gold (Au) copper (Cu) silver (Ag) sulfur (S) graphite (C)	monetary standard, jewelry coinage, electrical wiring, jewelry coinage, jewelry, photography sulfa drugs and chemicals; match heads; fireworks pencil lead, dry lubricant

Ores Many of the items just mentioned are made from ores. A mineral is an **ore** if it contains a valuable substance that can be mined at a profit. Hematite, for instance, is an ore that contains the element iron. Consider your classroom. If any items are made of iron, their original source might have been the mineral hematite. If there are items in the room made of aluminum, their original source was the ore bauxite. A common use of the metal titanium, obtained from the mineral ilmenite, is shown in **Figure 4.17.** **Table 4.4** summarizes the mineral groups and their major uses.

The classification of a mineral as an ore can also change if the supply of or demand for that mineral changes. Consider a mineral that is used to make computers. Engineers might develop a more efficient design or a less costly alternative material. In either of these cases, the mineral would no longer be used in computers. Demand for the mineral would drop. It would not be profitable to mine. The mineral would no longer be considered an ore.

Figure 4.17 Parts of this athlete's wheelchair are made of titanium. Its light weight and extreme strength makes it an ideal metal to use.

Mines Ores that are located deep within Earth's crust are removed by underground mining. Ores that are near Earth's surface are obtained from large, open-pit mines. When a mine is excavated, unwanted rock and dirt, known as gangue, are dug up along with the valuable ore. The overburden must be separated from the ore before the ore can be used. Removing the overburden can be expensive and, in some cases, harmful to the environment, as you will learn in Chapters 24 and 26. If the cost of removing the overburden becomes higher than the value of the ore itself, the mineral will no longer be classified as an ore. It would no longer be economical to mine.

Gems What makes a ruby more valuable than mica? Rubies are rarer and more visually pleasing than mica. Rubies are thus considered gems. **Gems** are valuable minerals that are prized for their rarity and beauty. They are very hard and scratch resistant. Gems such as rubies, emeralds, and diamonds are cut, polished, and used for jewelry. Because of their rareness, rubies and emeralds are more valuable than diamonds. **Figure 4.18** shows a rough diamond and a polished diamond.

In some cases, the presence of trace elements can make one variety of a mineral more colorful and more prized than other varieties of the same mineral. Amethyst, for instance, is the gem form of quartz. Amethyst contains traces of iron, which gives the gem a purple color. The mineral corundum, which is often used as an abrasive, also occurs as rubies and sapphires. Rubies contain trace amounts of chromium, while sapphires contain trace amounts of cobalt or titanium.

Figure 4.18 The real beauty of gemstones is revealed once they are cut and polished.

Section 4.2 Assessment

Section Summary

- In silicates, one silicon atom bonds with four oxygen ions to form a tetrahedron.
- Major mineral groups include silicates, carbonates, oxides, sulfides, sulfates, halides, and native elements.
- An ore contains a valuable substance that can be mined at a profit.
- Gems are valuable minerals that are prized for their rarity and beauty.

Understand Main Ideas

1. MAIN Idea **Formulate** a statement that explains the relationship between chemical elements and mineral properties.
2. **List** the two most abundant elements in Earth's crust. What mineral group do these elements form?
3. **Hypothesize** what some environmental consequences of mining ores might be.

Think Critically

4. **Hypothesize** why the mineral opal is often referred to as a mineraloid.
5. **Evaluate** which of the following metals is better to use in sporting equipment and medical implants: titanium—specific gravity = 4.5, contains only Ti; or steel—specific gravity = 7.7, contains Fe, O, Cr.

WRITING in Earth Science

6. Design a flyer advertising the sale of a mineral of your choice. You might choose a gem or industrially important mineral. Include any information that you think will help your mineral sell.

ON SITE: CRYSTALS AT LARGE IN MEXICO

Cave of Crystals, part of Naica Cave in Chihuahua, Mexico is known for its large crystals.

Eloy and Javier Delgado walk slowly into the Naica Cave in Chihuahua, Mexico. The cave is very hot, making it difficult for them to breathe. They enter a room in the cave and before them are huge 4.5-m crystals that are clear and brilliant. How did these crystals grow this large? What kinds of conditions make these crystals possible?

The climate inside the cave The large gypsum minerals are present in the Cave of Crystals, a room in Naica Cave, located 300 m below Earth's surface. Temperatures there hover around 58°C. The air here has a relative humidity of 100 percent. These extreme conditions mean that anyone entering the cave can remain only for a few minutes at a time.

Crystal formations in the cave The crystals in the Naica Cave are a crystalline form of gypsum called selenite. The crystals in this cave grow into three distinct shapes. Crystals that grow from the floor of the cave are plantlike in appearance. They are grayish in color from the mud that seeps into them as they grow. Swordlike crystals cover the walls of the cave. These crystals grow to lengths of 0.5 m to 1 m and are opaque white in color. Within the main room of the cave, there are crystals with masses of up to 27 kg and up to 8.25 m long and 1 m wide.

How did these crystals form? Crystals need several things in order to form. First, they need a space—in this case, a cave. Caves form as a result of water circulating along weak planes in a rock. Over time, the rock dissolves and a cave is formed. Second, crystals need a source of water that is rich in dissolved minerals. Crystal formation also depends on factors such as pressure, temperature, level of water in the cave, and the chemistry of the mineral-rich water.

In 2006, geologists determined that the crystals' massive sizes resulted from the steady temperature of about 58°C while the cave was full of mineral-rich water. As long as the crystals remained in this environment, they continued to grow. Because the crystals are so large, scientists think that the Cave of Crystals had these conditions for thousands of years.

WRITING in Earth Science

Research Visit glencoe.com to conduct research about the processes that form crystals in a cave. Pick a cave and make a brochure describing and illustrating the types of crystals found there.