ACTIVITY 3.2 Mineral Properties

THINK About It | **How and why do people study minerals?**

OBJECTIVE Analyze and describe the physical and chemical properties of minerals.

PROCEDURES

1. **Before you begin**, read the following background information. This is **what you will need**:
   - ____ Activity 3.2 Worksheets (pp. 102–103) and pencil
   - ____ set of mineral samples (obtained as directed by your instructor)
   - ____ set of mineral analysis tools (obtained as directed by your instructor)
   - ____ cleavage goniometer cut from GeoTools Sheet 1 at the back of the manual
2. **Then follow your instructor's directions** for completing the worksheets.

What Are a Mineral's Chemical and Physical Properties?

The **chemical properties** of a mineral are its characteristics that can only be observed and measured when or after it undergoes a chemical change due to reaction with another material. This includes things like if or how it tarnishes (reacts with air or water) and whether or not it reacts with acid. For example, calcite and other carbonate (CO_3-containing) minerals react with acid, and native copper tarnishes to a dull brown or green color when it reacts with air or water.

The **physical properties** of a mineral are its characteristics that can be observed (and sometimes measured) without changing its composition. This includes things like how it looks (color, luster, clarity) before it tarnishes or weathers by reacting with air or water, how well it resists scratching (hardness), how it breaks or deforms under stress (cleavage, fracture, tenacity), and the shapes of its crystals. For example, quartz crystals are hard to scratch, glassy, and transparent, while talc is easily scratched, opaque, and feels greasy.

In this activity, you will use the properties of color and clarity (before and after tarnishing), crystal form, luster (before and after tarnishing), streak, hardness, cleavage, and fracture to describe mineral samples. Additional properties—such as tenacity, reaction with acid, magnetic attraction, specific gravity, striations, and exsolution lamellae—can also be helpful in analyzing particular minerals.

Color and Clarity. A mineral's **color** is usually its most noticeable property and may be a clue to its identity. Minerals normally have a typical color, like gold. A rock made up of one color of mineral crystals is usually made up of one kind of mineral, and a rock made of more than one color of mineral crystals is usually made up of more than one kind of mineral. However, there are exceptions, like the agate in **FIGURE 3.1D**. It has many colors, but they are simply *varieties* (var.)—different colors—of the mineral quartz. This means that a mineral cannot be identified solely on the basis of its color. The mineral's other properties must also be observed, recorded, and used collectively to identify it. Most minerals also tend to exhibit one color on freshly broken surfaces and a different color on tarnished or weathered surfaces. Be sure to note this difference, if present, to aid your identification.

Mineral crystals may vary in their **clarity**: degree of transparency or their ability to transmit light. They may be *transparent* (clear and see-through, like window glass), *translucent* (foggy, like looking through a steamed-up shower door), or *opaque* (impervious to light, like concrete and metals). It is good practice to record not only a mineral's color, but also its clarity. For example, the crystals in **FIGURE 3.1B** are purple in color and have transparent to translucent clarity. Galena mineral crystals (**FIGURE 3.2**) are opaque.

Crystal Forms and Mineral Habits. The geometric shape of a crystal is its **crystal form**. Each form is bounded by flat **crystal faces** that intersect at specific angles and in symmetrical relationships (**FIGURE 3.1A** and **B**). The crystal faces are the outward reflection of the way that atoms or groups of atoms bonded together in a three-dimensional pattern as the crystal grew under specific environmental conditions. There are many named crystal forms (**FIGURE 3.4**). Combinations of two or more crystals can also form named patterns, shapes, or twins (botryoidal, dendritic, radial, fibrous: **FIGURE 3.4**). A mass of mineral crystals lacking a distinctive pattern of crystal growth is called *massive*.

Development of Crystal Faces. The terms euhedral, subhedral, and anhedral describe the extent to which a crystal's faces and form are developed. *Euhedral crystals* have well developed crystal faces and clearly defined and recognizable crystal forms (**FIGURE 3.1A**). They develop only if a mineral crystal is unrestricted as it grows. This is rare. It is more common for mineral crystals to crowd together as they grow, resulting in a massive network of intergrown crystals with deformed crystal faces and odd shapes or imperfect crystal forms (**FIGURE 3.1B**). *Subhedral* crystals are imperfect but have enough crystal faces that their forms are recognizable. *Euhedral* crystals have no crystal faces, so they have no recognizable crystal form (**FIGURE 3.1C**). Most of the laboratory samples of minerals that you will analyze do not exhibit their crystal forms because they are small broken pieces of larger crystals. But whenever the form or system of crystals in a mineral sample can be detected, then it should be noted and used as evidence for mineral identification.

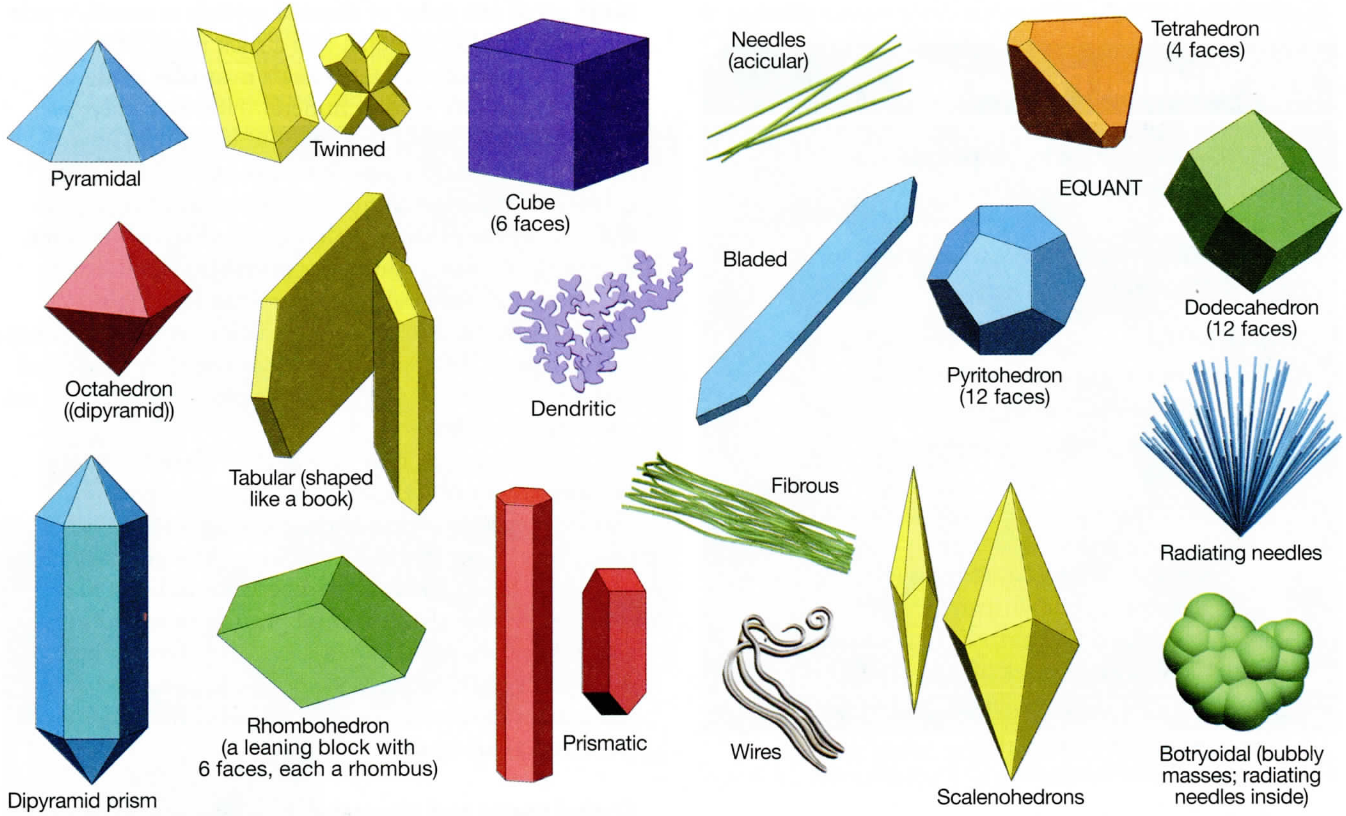


FIGURE 3.4 Crystal forms and combinations. *Crystal form* is the geometric shape of a crystal, and is formed by intersecting flat outer surfaces called *crystal faces*. Combinations of two or more crystals can form patterns, shapes, or twins that also have names. *Massive* refers to a combination of mineral crystals so tightly inter-grown that their crystal forms cannot be seen in hand sample.

Crystal Systems. Each specific crystal form can be classified into one of six *crystal systems* (**FIGURE 3.5**) according to the number, lengths, and angular relationships of imaginary geometric axes along which its crystal faces grew. The crystal systems comprise 32 classes of crystal forms, but only the common crystal forms are illustrated in **FIGURE 3.5**.

Mineral Habit. A mineral's **habit** is the characteristic crystal form(s) or combinations (clusters, coatings, twinned pairs) that it habitually makes under a given set of environmental conditions. Pyrite forms under a variety of environmental conditions so it has more than one habit. Its habit is cubes, pyritohedrons, octahedrons, or massive (**FIGURE 3.4**).

Luster. A mineral's **luster** is a description of how light reflects light from its surfaces. Luster is of two main types—metallic and nonmetallic—that vary in intensity from bright (very reflective, shiny, polished) to dull (not very reflective, not very shiny, not polished). For example, if you make a list of objects in your home that are made of metal (e.g., coins, knives, keys, jewelry, door hinges, aluminum foil), then you are already familiar with metallic luster. Yet the metallic objects can vary from bright (very reflective—like polished jewelry, the polished side of aluminum foil, or new coins) to dull (non-reflective—like unpolished jewelry or the unpolished side of aluminum foil).

Metallic Luster. Minerals with a **metallic luster (M)** reflect light just like the metal objects in your home—they have opaque, reflective surfaces with a silvery, gold, brassy, or coppery sheen (**FIGURES 3.2B**, **3.6A**, **3.7A**).

Nonmetallic Luster. All other minerals have a **nonmetallic luster (NM)**—a luster unlike that of the metal objects in your home (**FIGURES 3.1**, **3.2A**, **3.3**). The luster of nonmetallic minerals can also be described with the more specific terms below:

- Vitreous—very reflective luster resembling freshly broken glass or a glossy photograph
- Waxy—resembling the luster of a candle
- Pearly—resembling the luster of a pearl
- Earthy (dull)—lacking reflection, like dry soil
- Greasy—resembling the luster of grease, oily

Tarnish and Submetallic Luster. Most metallic minerals will normally tarnish (chemically weather) to a more dull nonmetallic luster, like copper coins. Notice how the exposed metallic copper crystals in **FIGURE 3.6** and the galena crystals in **FIGURE 3.2A** have tarnished to a nonmetallic luster. Always observe freshly broken surfaces of a mineral (e.g., **FIGURE 3.2B**) to determine whether it has a metallic or nonmetallic luster. It is also useful to note a mineral's luster on fresh versus tarnished

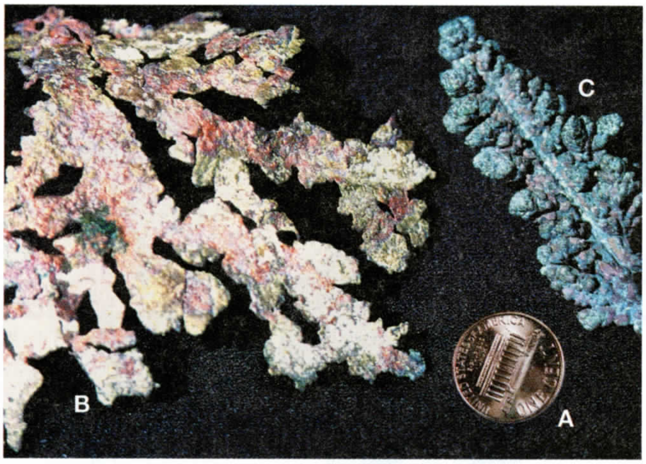


FIGURE 3.6 Native elements. The native elements are minerals composed of just one element, like gold nuggets. **A.** When freshly formed or broken, native copper (Cu, naturally-occurring pure copper) has a reflective metallic luster like this freshly-minted copper coin. However, these dendritic clusters of native copper crystals have tarnished to nonmetallic dull brown (A) and/or green (B) colors.

surfaces when possible. If you think that a mineral's luster is *submetallic*, between metallic and nonmetallic, then it should be treated as metallic for identification purposes.

Streak. Streak is the color of a mineral or other substance after it has been ground to a fine powder (so fine that you cannot see the grains of powder). The easiest way to do this is simply by scratching the mineral back and forth across a hard surface such as concrete, or a square of unglazed porcelain (called a *streak plate*). The color of the mineral's fine powder is its streak. Note that the brassy mineral in **FIGURE 3.7** has a dark gray streak, but the reddish silver mineral has a red-brown streak. A mineral's streak is usually similar even among all of that mineral's varieties.

If you encounter a mineral that is harder than the streak plate, it will scratch the streak plate and make a white streak of powder from the streak plate. The streak of such hard minerals can be determined by crushing a tiny piece of them with a hammer (if available). Otherwise, record the streak as unknown.

Hardness (H). A mineral's **hardness** is a measure of its resistance to scratching. A harder substance will scratch a softer one (**FIGURE 3.8**). German mineralogist Friedrich Mohs (1773–1839) developed a quantitative scale of relative mineral hardness on which the softest mineral (talc) has an arbitrary hardness of 1 and the hardest mineral (diamond) has an arbitrary hardness of 10. Higher-numbered minerals will scratch lower-numbered minerals (e.g., diamond will scratch talc, but talc cannot scratch diamond). **Mohs Scale of Hardness** (**FIGURE 3.9**) is widely used by geologists and engineers. When identifying a mineral, you should mainly be able to distinguish minerals that are relatively hard (6.0 or higher on Mohs Scale) from minerals that are relatively soft (less than or equal to 5.5 on Mohs Scale). You can use common objects such as a glass plate (**FIGURE 3.9**), pocket knife, or steel masonry nail to make this distinction as follows.

- **Hard minerals:** Will scratch glass; cannot be scratched with a knife blade or masonry nail.
- **Soft minerals:** Will not scratch glass; can be scratched with a knife blade or masonry nail.

You can determine a mineral's hardness number on Mohs Scale by comparing the mineral to common objects

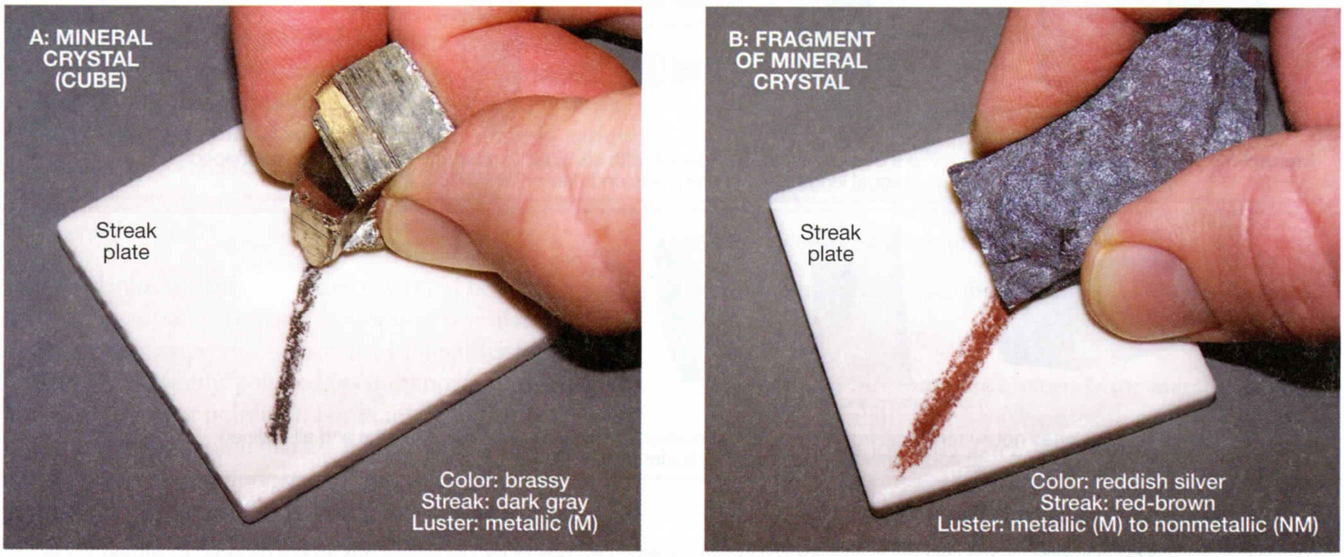


FIGURE 3.7 Streak tests. Determine a mineral's streak (color in powdered form) by scratching it across a streak plate with significant force, then blowing away larger pieces of the mineral to reveal the color of the powder making the streak. If you do not have a streak plate, then determine the streak color by crushing or scratching part of the sample to see the color of its powdered form.

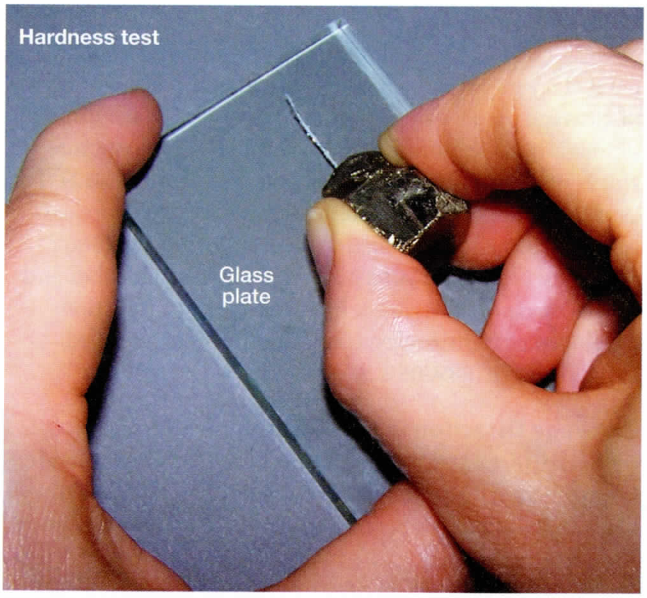
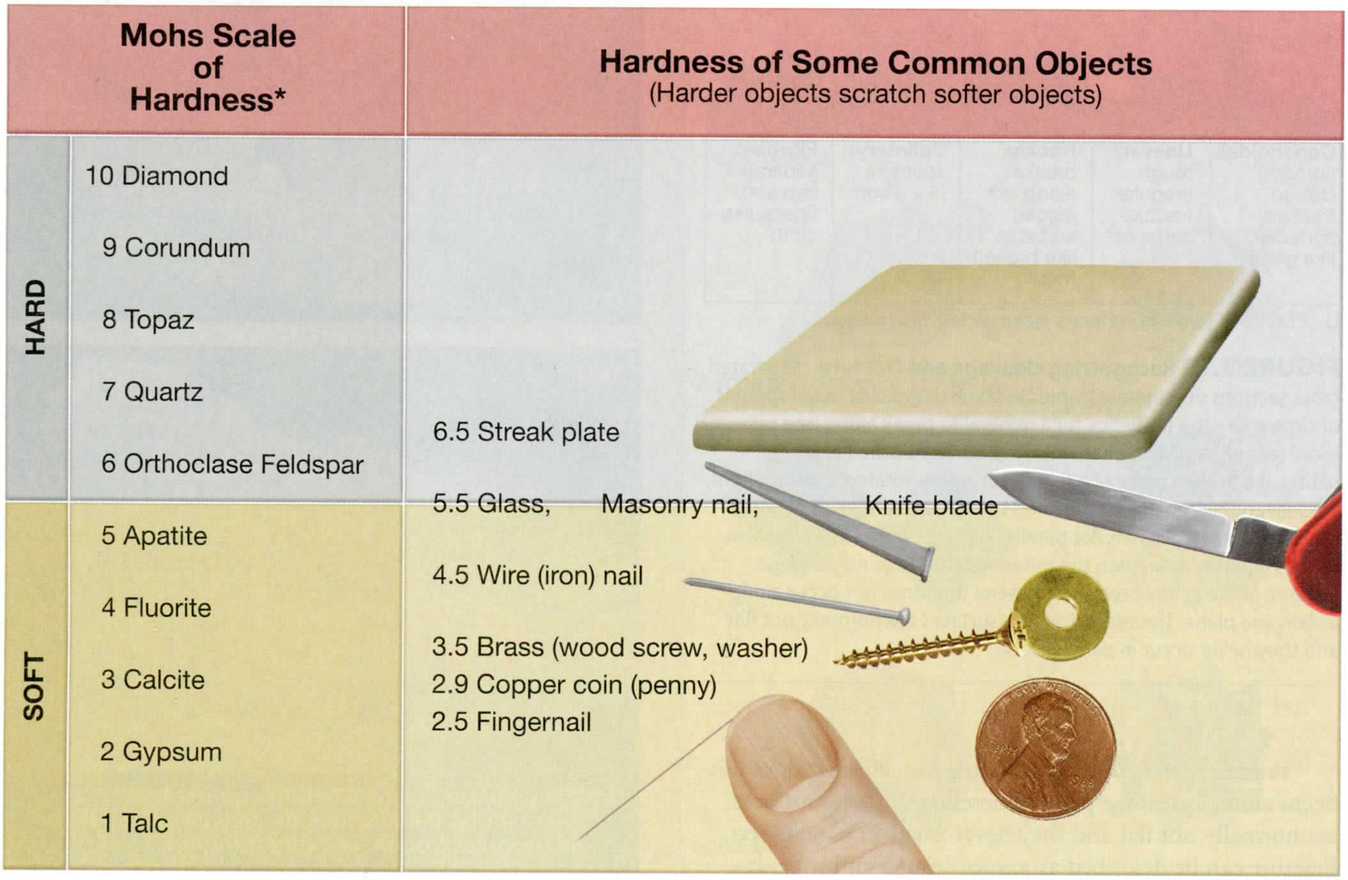


FIGURE 3.8 Hardness test. You can test a mineral's hardness (resistance to scratching) using a glass plate, which has a hardness of 5.5 on Mohs Scale of Hardness (**FIGURE 3.9**). Be sure the edges of the glass have been dulled. If not, then wrap the edges in masking tape or duct tape. Hold the glass plate firmly against a flat table top, then forcefully try to scratch the glass with the mineral sample. A mineral that scratches the glass is a *hard* mineral (i.e., harder than 5.5). A mineral that does not scratch the glass is a *soft* mineral (i.e., less than or equal to 5.5).

shown in **FIGURE 3.9** or pieces of the minerals in Mohs Scale. Commercial *hardness kits* contain a set of all of the minerals in **FIGURE 3.9** or a set of metal scribes of known hardnesses. When using such kits to make hardness comparisons, remember that the harder mineral/object is the one that scratches, and the softer mineral/object is the one that is scratched.

Cleavage and Fracture. Cleavage is the tendency of some minerals to break (*cleave*) along flat, parallel surfaces (**cleavage planes**) like the flat surfaces on broken pieces of galena (**FIGURE 3.2B**). Cleavage planes are surfaces of weak chemical bonding (attraction) between repeating, parallel layers of atoms in a crystal. Each different set of parallel cleavage planes is referred to as a *cleavage direction*. Cleavage can be described as excellent, good, or poor (**FIGURE 3.10**). An *excellent cleavage* direction reflects light in one direction from a set of obvious, large, flat, parallel surfaces. A *good cleavage* direction reflects light in one direction from a set of many small, obvious, flat, parallel surfaces. A *poor cleavage* direction reflects light from a set of small, flat, parallel surfaces that are difficult to detect. Some of the light is reflected in one direction from the small cleavage surfaces, but most of the light is scattered randomly by fracture surfaces separating the cleavage surfaces.



* A scale for measuring relative mineral hardness (resistance to scratching).

FIGURE 3.9 Mohs Scale of Hardness (resistance to scratching). *Hard minerals* have a Mohs hardness number greater than 5.5, so they scratch glass and cannot be scratched with a knife blade or masonry (steel) nail. *Soft minerals* have a Mohs hardness number of 5.5 or less, so they do not scratch glass and are easily scratched by a knife blade or masonry (steel) nail. A mineral's hardness number can be determined by comparing it to the hardness of other common objects or minerals of Mohs Scale of Hardness.

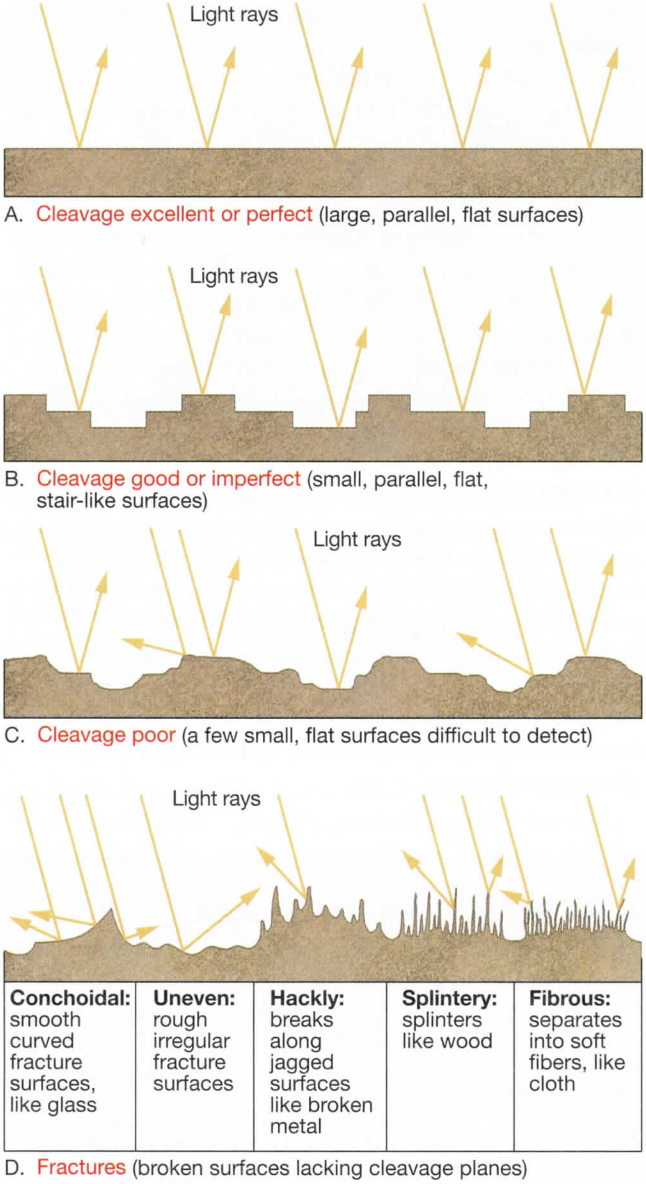


FIGURE 3.10 Recognizing cleavage and fracture. Illustrated cross sections of mineral samples to show degrees of development of cleavage—the tendency for a mineral to break along one or more sets of parallel, planar, reflective surfaces called *cleavage planes*. If a broken piece of a mineral crystal is rotated in bright light, its cleavage planes will be revealed by periodic flashes of light from one large, or many small, flat parallel surfaces. If no such reflective flashes of light occur, then the mineral sample has no cleavage. *Fracture* refers to any break in a mineral that does not occur along a cleavage plane. Therefore, fracture surfaces are normally not flat and they never occur in parallel sets.

Fracture refers to any break in a mineral that does not occur along a cleavage plane. Therefore, fracture surfaces are normally not flat and they never occur in parallel sets. Fracture can be described as *uneven* (rough and irregular, like the milky quartz in FIGURE 3.11B), *splintery* (like splintered wood), or *hackly* (having jagged edges, like broken metal). Pure quartz (FIGURE 3.11A) and mineraloids like opal (FIGURE 3.3) tend to fracture like glass—along ribbed, smoothly curved surfaces called *conchoidal fractures*.

Cleavage Direction. Cleavage planes are parallel surfaces of weak chemical bonding (attraction) between repeating parallel layers of atoms in a crystal, and more than one set of cleavage planes can be present in a crystal. Each different set has an orientation relative to the crystalline structure and is referred to as a **cleavage direction** (FIGURE 3.12). For example, muscovite (FIGURE 3.13) has one excellent cleavage direction and splits apart like pages of a book (book cleavage). Galena (FIGURE 3.2) breaks into small cubes and shapes made of cubes, so it has three cleavage directions developed at right angles to one another. This is called cubic cleavage (FIGURE 3.12).

Cleavage Direction in Pyriboles. Minerals of the pyroxene (e.g., augite) and amphibole (e.g., hornblende) groups generally are both dark-colored (dark green to black), opaque, nonmetallic minerals that have two good

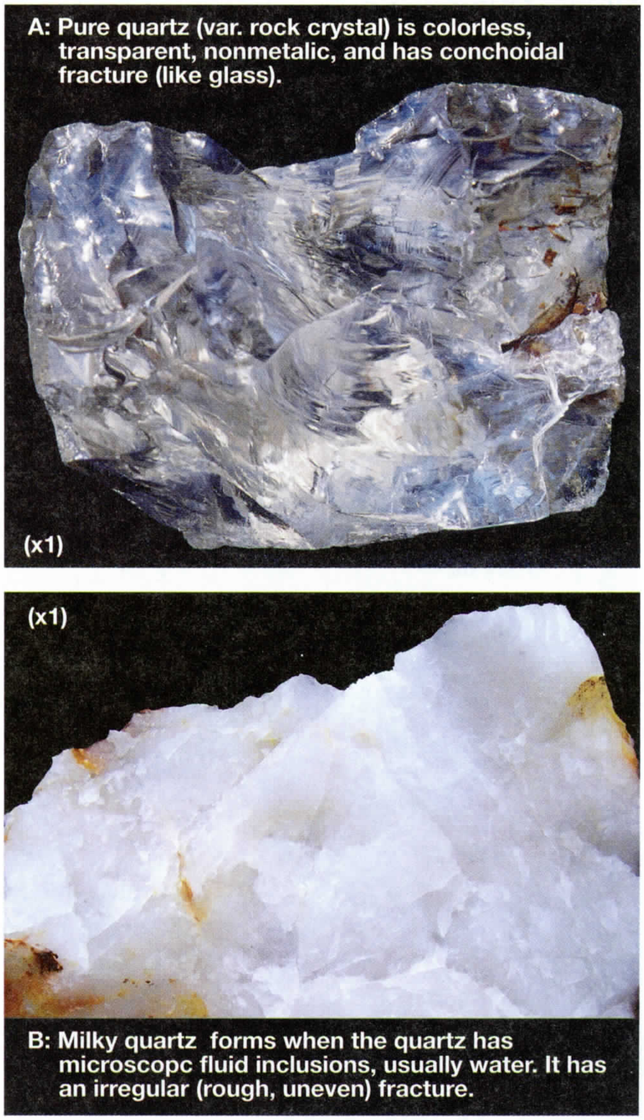


FIGURE 3.11 Fracture in quartz—SiO_2 (silicon dioxide). These hand samples are broken pieces of quartz mineral crystals so no crystal faces are present. Note the absence of cleavage and the presence of conchoidal (like glass) to uneven fracture.

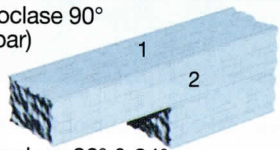
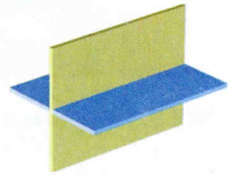
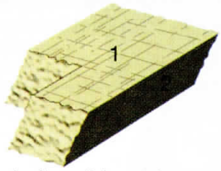
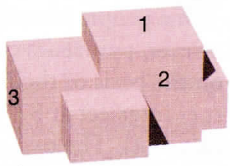
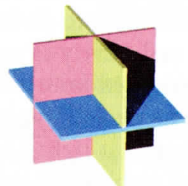
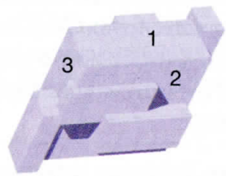
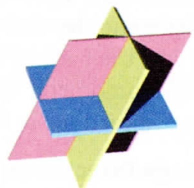
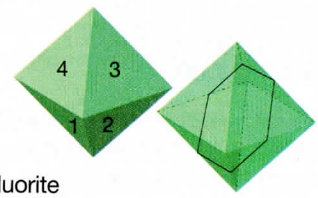
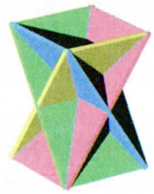
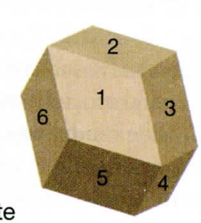
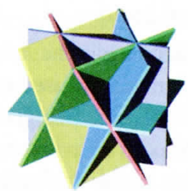
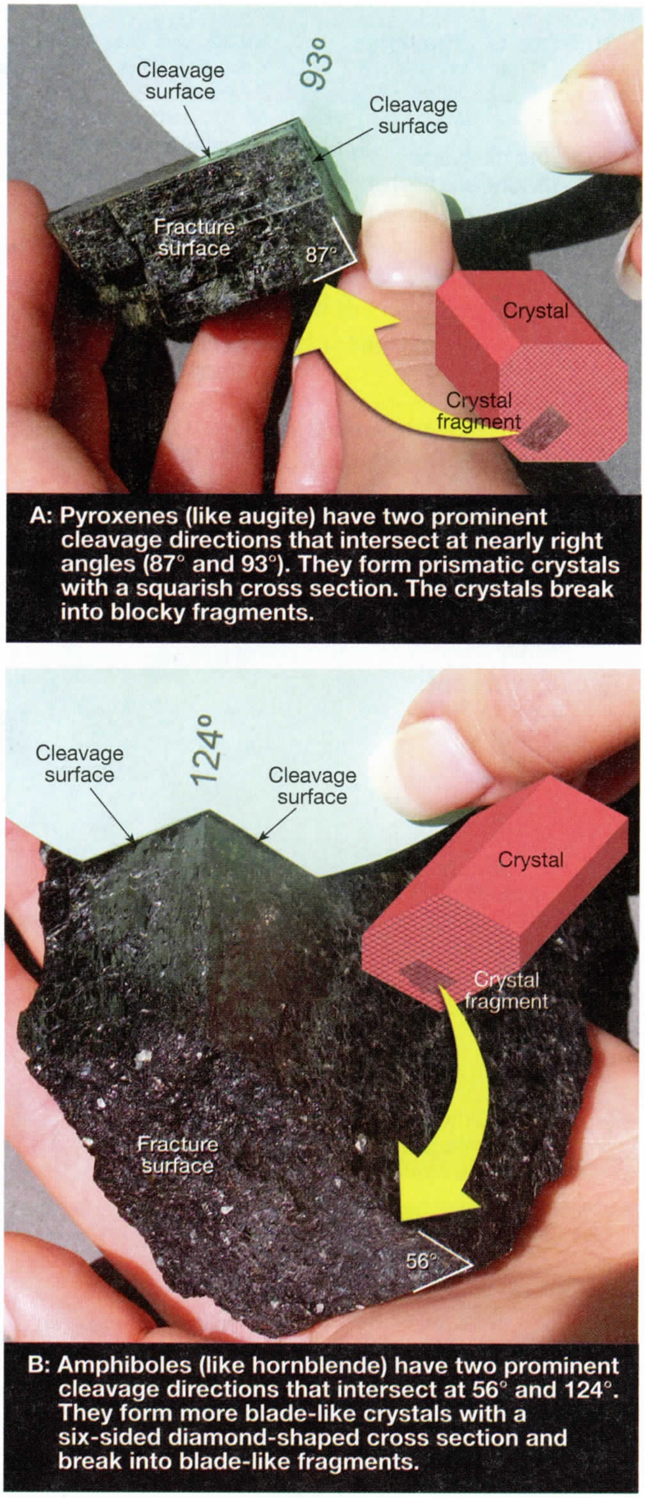
Number of Cleavages and Their Directions	Name and Description of How the Mineral Breaks	Shape of Broken Pieces (cleavage directions are numbered)	Illustration of Cleavage Directions
No cleavage (fractures only)	No parallel broken surfaces; may have conchoidal fracture (like glass)	 Quartz	None (no cleavage)
1 cleavage	**Basal (book) cleavage** "Books" that split apart along flat sheets	 Muscovite, biotite, chlorite (micas)	
2 cleavages intersect at or near 90°	**Prismatic cleavage** Elongated forms that fracture along short *rectangular* cross sections	Orthoclase 90° (K-spar)  Plagioclase 86° & 94°, pyroxene (augite) 87° & 93°	
2 cleavages do not intersect at 90°	**Prismatic cleavage** Elongated forms that fracture along short *parallelogram* cross sections	 Amphibole (hornblende) 56° & 124°	
3 cleavages intersect at 90°	**Cubic cleavage** Shapes made of cubes and parts of cubes	 Halite, galena	
3 cleavages do not intersect at 90°	**Rhombohedral cleavage** Shapes made of rhombohedrons and parts of rhombohedrons	 Calcite and dolomite 75° & 105°	
4 main cleavages intersect at 71° and 109° to form octahedrons, which split along hexagon-shaped surfaces; may have secondary cleavages at 60° and 120°	**Octahedral cleavage** Shapes made of octahedrons and parts of octahedrons	 Fluorite	
6 cleavages intersect at 60° and 120°	**Dodecahedral cleavage** Shapes made of dodecahedrons and parts of dodecahedrons	 Sphalerite	

FIGURE 3.12 **Cleavage in minerals.**

FIGURE 3.13 Cleavage in mica. Mica is a group of silicate minerals that form very reflective (vitreous) tabular crystals with one excellent cleavage direction. The crystals split easily into thin sheets, like pages of a book. This is called *book cleavage*. Muscovite mica is usually silvery brown in color. Biotite mica is always black.



A: Pyroxenes (like augite) have two prominent cleavage directions that intersect at nearly right angles (87° and 93°). They form prismatic crystals with a squarish cross section. The crystals break into blocky fragments.

B: Amphiboles (like hornblende) have two prominent cleavage directions that intersect at 56° and 124°. They form more blade-like crystals with a six-sided diamond-shaped cross section and break into blade-like fragments.

FIGURE 3.14 Cleavage in pyroxenes and amphiboles. Pyroxenes and amphiboles are two groups of dark colored silicate minerals with many similar properties. The main feature that distinguishes them is their cleavage.

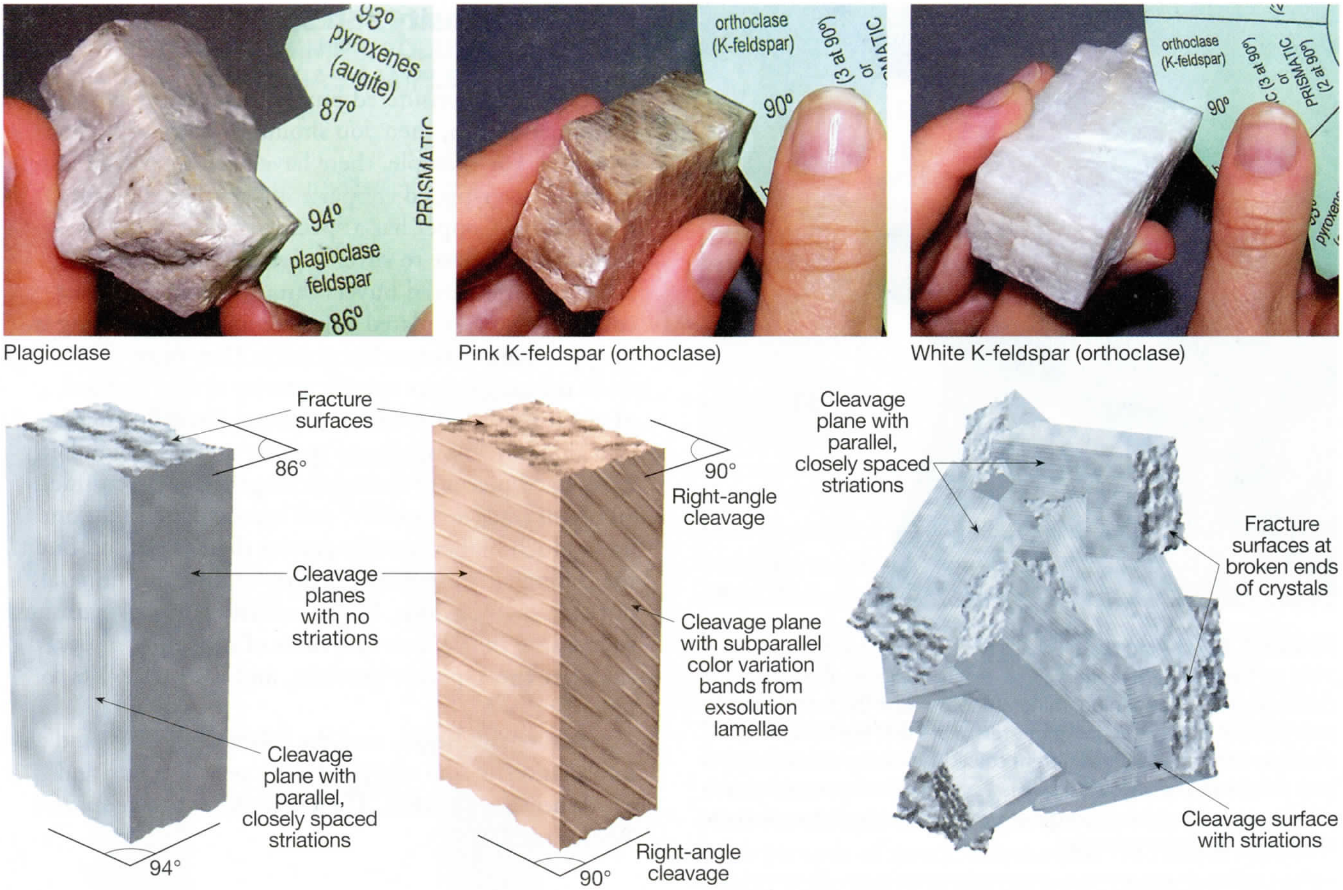
cleavage directions. The two groups of minerals are sometimes difficult to distinguish, so some people identify them collectively as *pyriboles*. However, pyroxenes can be distinguished from amphiboles on the basis of their cleavage. The two cleavages of pyroxenes intersect at 87° and 93°, nearly at right angles (**FIGURE 3.14A**). The two cleavages of amphiboles intersect at angles of 56° and 124° (**FIGURE 3.14B**). These angles can be measured in hand samples using the cleavage goniometer from GeoTools Sheet 1 at the back of this manual. Notice how a green cleavage goniometer was used to measure angles between cleavage directions in **FIGURE 3.14**.

Cleavage Direction in Feldspars. Feldspars have two excellent to good cleavage directions, plus uneven fracture (**FIGURE 3.15**). The cleavage goniometer from GeoTools Sheet 1 can be used to distinguish potassium feldspar (orthoclase) from plagioclase (**FIGURE 3.15**).

Other Properties. There are additional mineral properties, too numerous to review here. However, the following other properties are typical of specific minerals or mineral groups:

Tenacity is the manner in which a substance resists breakage. Terms used to describe mineral tenacity include *brittle* (shatters like glass), *malleable* (like modeling clay or gold; can be hammered or bent permanently into new shapes), *elastic* or *flexible* (like a plastic comb; bends but returns to its original shape), and *sectile* (can be carved with a knife).

Reaction to acid differs among minerals. Cool, dilute hydrochloric acid (1–3% HCl) applied from a dropper bottle is a common "acid test." All of the so-called *carbonate minerals* (minerals with a chemical composition including carbonate, CO_3) will effervesce ("fizz") when a drop of such dilute HCl is applied to one of their freshly exposed surfaces (**FIGURE 3.16**). Calcite ($CaCO_3$) is the most commonly encountered carbonate mineral and effervesces in the acid test. Dolomite $[Ca,Mg(CO_3)_2]$ is



A. Plagioclase **B. Pink K-feldspar (orthoclase)** **C. Rock comprised of plagioclase crystals**

FIGURE 3.15 Common feldspars. Note how the cleavage goniometer can be used to distinguish potassium feldspar (K-spar, orthoclase) from plagioclase. The K-spar or orthoclase (Greek, *ortho*—right angle and *clase*—break) has perfect right-angle (90º) cleavage. Plagioclase (Greek, *plagio*—oblique angle and *clase*—break) does not. A. Plagioclase often exhibits *hairline striations* on some of its cleavage surfaces. They are caused by *twinning*: microscopic intergrowths between symmetrically-paired microcrystalline portions of the larger crystal. B. K-par (orthoclase) crystals may have intergrowths of thin, discontinuous, *exsolution lamellae*. They are actually microscopic layers of plagioclase that form as the K-spar cools, like fat separates from soup when it is refrigerated. C. Hand sample of a rock that is an aggregate of intergrown plagioclase mineral crystals. Individual mineral crystals are discernible within the rock, particularly the cleavage surfaces that have characteristic hairline striations.

another carbonate mineral that resembles calcite, but it will fizz in dilute HCl only if the mineral is first powdered. (It can be powdered for this test by simply scratching the mineral's surface with the tip of a rock pick, pocket knife, or nail.) If HCl is not available, then undiluted vinegar can be used for the acid test. It contains acetic acid (but the effervescence will be much less violent).

Striations are straight "hairline" grooves on the cleavage surfaces or crystal faces of some minerals. This can be helpful in mineral identification. For example, you can use the striations of plagioclase feldspar (**FIGURE 3.15A**) to distinguish it from potassium feldspar (K-feldspar, **FIGURE 3.15B**). *Plagioclase feldspar* has faint hairline striations on surfaces of one of its two cleavage directions. In contrast, *K- feldspar* (orthoclase) sometimes has internal *exsolution lamellae,* which are faint streaks of plagioclase that grew inside of it.

Magnetism influences some minerals, such as magnetite. The test is simple: check to see if the mineral is attracted to a magnet. Lodestone is a variety of magnetite that is itself a natural magnet. It will attract steel paperclips. Some other minerals may also be weakly attracted to a magnet (e.g., hematite, bornite, and pyrrhotite).

Specific Gravity (SG). Density is a measure of an object's mass (weighed in grams, g) divided by its volume (in cubic centimeters, cm^3). **Specific gravity** is the ratio of the density of a substance divided by the density of water. Since water has a density of 1 g/cm^3 and the units cancel out, specific gravity is the same number as density but without any units. For example, the mineral quartz has a density of 2.65 g/cm^3 so its specific gravity is 2.65 (i.e., SG = 2.65). **Hefting** is an easy way to judge the specific gravity of one mineral relative to another. This is done by holding a piece of the first mineral in one hand and holding an equal-sized piece of the second mineral in your other hand. Feel the difference in weight between the two samples (i.e., heft the samples). The sample that feels heavier has a higher specific gravity than the other. Most metallic minerals have higher specific gravities than nonmetallic minerals.

FIGURE 3.16 Acid test. Place a drop of weak hydrochloric acid (HCl) on the sample. If it effervesces (reacts, bubbles), then it is a carbonate (CO_{3-} containing) mineral. Please wipe the sample dry with a paper towel after doing this test! Note that the mineral in this example occurs in several different colors and can be scratched by a wire (iron) nail. The yellow sample is a crystal of this mineral, but the other samples are broken pieces of crystals that reveal the mineral's characteristic cleavage angles.

ACTIVITY 3.3 Determining Specific Gravity (SG)

THINK About It | **How and why do people study minerals?**

OBJECTIVE Measure the volume and mass of minerals, calculate their specific gravities, and use the results to identify them.

PROCEDURES

1. **Before you begin,** read the following background information. Your instructor will provide laboratory equipment, but this is **what you will need** to bring to lab:
   ___ Activity 3.3 Worksheet (p. 104) and pencil
   ___ calculator
2. **Then follow your instructor's directions** about where to obtain laboratory equipment and mineral samples, how to work safely, and how to complete the worksheet.

Why Are Density and Specific Gravity Important?

Have you ever considered buying silver coins as an investment? If so, then you should be wary of deceptive sales. For example, there have been reports of less valuable silver-plated copper coins marketed as pure silver coins. Copper has a specific gravity of 8.94, which is very close to silver's specific gravity of 9.32. So, even experienced buyers cannot tell a solid silver coin from a silver-plated copper coin just by hefting it to approximate its specific gravity. They must determine the coin's exact specific gravity as one method of ensuring its authenticity. Mineral identification is also aided by knowledge of specific gravity. If you heft same-sized pieces of the minerals galena (lead sulfide, an ore of lead) and quartz, you can easily tell that one has a much higher specific gravity than the other. But the difference in specific gravities of different minerals is not always so obvious. In this activity you will learn how to measure the volume and mass of mineral samples, calculate their specific gravities, and use the results to identify them.

Before you begin, read the following background information and be sure you have a pencil, eraser, and Worksheet 3.3 (p. 102). **Then** complete the activity and Worksheet 3.3.

How to Determine Volume. Recall that **volume** is the amount of space that an object takes up. Most mineral samples have odd shapes, so their volumes cannot be calculated from linear measurements. Their volumes must be determined by measuring the volume of water they displace. This is done in the laboratory with a *graduated cylinder* (FIGURE 3.17), an instrument used to measure volumes of fluid (fluid volume). Most graduated cylinders are graduated in metric units called milliliters (mL or ml), which are thousandths of a liter. *You should also note that 1 mL (1 ml) of fluid volume is exactly the same as 1 cm^3 of linear volume.*

Procedures for determining the volume of a mineral sample are provided in FIGURE 3.17. Note that when you pour water into a glass graduated cylinder, the surface of the liquid is usually a curved *meniscus*, and the volume is read at the bottom of its concave surface. In most plastic graduated cylinders, however, there is no meniscus. The water level is flat and easy to read.

If you slide a mineral sample into a graduated cylinder full of water (so no water splashes out), then it takes up space previously occupied by water at the bottom of the graduated cylinder. This displaced water has nowhere to go except higher into the graduated cylinder. Therefore, the volume of the mineral sample is exactly the same as the volume of fluid (water) that it displaces.