Minerals

Definition

A mineral is a naturally occurring, crystalline, inorganic, homogeneous solid with a chemical composition that is either fixed or varies within certain fixed limits, and a characteristic internal structure manifested in its exterior form and physical properties.

Mineral Identification

Common minerals are identified or recognized by testing them for general or specific physical properties. For example, the common substance table salt is actually a mineral composed of sodium chloride (NaCl) and bears the mineral name halite. The taste of halite is distinctive and is sufficient for identifying and distinguishing it from other substances such as sugar (not a mineral) that have a similar appearance. Chemical composition alone is not sufficient to identify minerals. The mineral graphite and the mineral diamond are both composed of a single element, carbon (C), but their physical properties are very different.

The taste test applied to halite is restrictive because it is the only mineral that can be so identified. Other minerals may have a specific taste different from that of halite. Other common minerals can be tested by visual inspection for the physical properties of **crystal form, cleavage,** or **color,** or by using simple tools such as a knife blade or glass plate to test for the physical property of hardness.

The first step in learning how to identify common minerals is to become acquainted with the various physical properties that individually or collectively characterize a mineral specimen.

Properties of Minerals

The physical properties of minerals are those that can be observed generally in all minerals. They include such common features as luster, color, hardness, cleavage, streak, and specific gravity. **Special properties** are those that are found in only a few minerals. These include magnetism, double refraction, taste, odor, feel, and chemical reaction with acid.

In your work in the laboratory, use the hand specimens sparingly when applying tests for the various properties.

General Physical Properties

Luster

The appearance of a fresh mineral surface in reflected light is its **luster.** A mineral that looks like a metal is said to have a **metallic luster.** Minerals that are **nonmetallic** are described by one of the following adjectives: **vitreous** (having the luster of glass); **resinous** (having the luster of resin); **pearly; silky; dull** or **earthy** (not bright or shiny).

Your laboratory instructor will display examples of minerals that possess these various lusters.

Color

The **color** of a mineral is determined by examining a fresh surface in reflected light. Color and luster are not the same. Some minerals are clear and transparent; others are opaque. The color or lack of color may be diagnostic in some minerals, but in others, the color varies due to a slight difference in chemical composition or to small amounts of impurities within the mineral. The variations in color of a mineral are called **varieties** of that mineral (fig. 1.1).

Figure 1.1

The specimens in this photograph are all varieties of quartz. The difference in colors is due to various impurities. Clockwise from left: smoky quartz, rock crystal, rose quartz, citrine, amethyst.

PART I

Earth Materials

Background

The materials that make up the crust of the earth fall into two broad categories: minerals and rocks. Minerals are elements or chemical compounds formed by a number of natural processes. Rocks are aggregates of minerals or organic substances that occur in many different architectural forms over the face of the earth, and they contain a significant part of the geologic history of the region where they occur. To identify them and understand their history, you must be able to identify the minerals that make up the rocks.

The goal of Part I is to introduce students of geology to the identification of minerals and rocks through the use of simplified identification methods and classification schemes. Students will be provided with samples of minerals and rocks in the laboratory. These samples are called **hand specimens.** Ordinarily their study does not require a microscope or any means of magnification because the naked or corrected eye is sufficient to perceive their diagnostic characteristics. A feature of a mineral or rock that can be distinguished without the aid of magnification is said to be **macroscopic** (also **megascopic**) in size. Conversely, a feature that can be identified only with the aid of magnifiers is said to be **microscopic** in size. The exercises that deal with the identification and classification of minerals and rocks in Part I are based only on macroscopic features.

Hardness

The **hardness** of a mineral is its resistance to abrasion (scratching). Hardness can be determined either by trying to scratch a mineral of unknown hardness with a substance of known hardness or by using the unknown mineral to scratch a substance of known hardness. Hardness is determined on a relative scale (linear scale) called the **Mohs scale of hardness,** which consists of 10 common minerals arranged in order of their increasing hardness (table 1.1). In the laboratory, convenient materials other than these 10 specific minerals may be used for determining hardness.

In contrast to the Mohs scale, the Vickers scale is an example of a nonlinear scale that points out the great difference in hardness between the various minerals (fig. 1.2). Nonlinear hardness scales are used to test the hardness of materials, for example, by measuring the volume of an indentation left in the surface of the material under a known pressure.

In this manual, a mineral that scratches glass will be considered "hard," and one that does not scratch glass will be considered "soft." In making hardness tests on a glass plate, do not hold the glass in your hand; keep it firmly on the table top. If you think that you made a scratch on the glass, try to rub the scratch off. What appears to be a scratch may only be some of the mineral that has rubbed off on the glass.

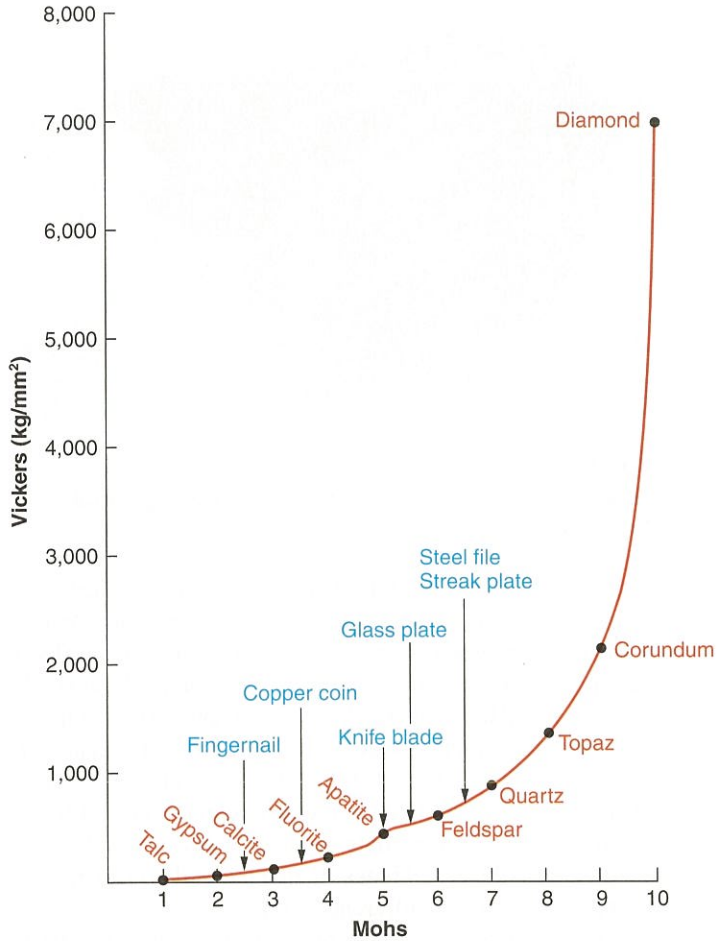


Figure 1.2
Mohs hardness scale plotted against Vickers indentation values (kg/mm^2).

Table 1.1 Mineral Hardness According to the Mohs Scale (A) and Some Common Materials (B)

Hardness	A	B
1	Talc	
2	Gypsum	
2.5		Fingernail
3	Calcite	
3.5		Copper coin
4	Fluorite	
5	Apatite	
5–5.5		Knife blade
5.5		Glass plate
6	Feldspar	
6.5		Steel file, Streak plate
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

Cleavage

Cleavage is the tendency of a mineral to break along definite planes of weakness that exist in the internal (atomic) structure of the mineral. Cleavage planes are related to the crystal system of the mineral and are always parallel to crystal faces or possible crystal faces. Cleavage may be conspicuous and is a characteristic physical property that is useful in mineral identification. It is almost impossible to break some minerals in such a way that cleavage planes do not develop. An example is calcite, with its rhombohedral cleavage.

Perfect cleavage describes cleavage planes with surfaces that are very smooth and flat and that reflect light much like a mirror. Other descriptors such as **good, fair,** and **poor** are used to describe cleavage surfaces that are less well defined. Some minerals exhibit excellent crystal faces but have no cleavage; quartz is such a mineral.

The cleavage surfaces of some minerals such as calcite, muscovite (fig. 1.3), halite, and fluorite are so well developed that they are easily detected. In others, the cleavage surfaces may be so discontinuous as to escape detection by casual

Figure 1.3

Muscovite is a mineral with one direction of cleavage (basal cleavage).

inspection. Before deciding that a mineral has no cleavage, turn it around in a strong light and observe whether there is some position in which the surface of the specimen reflects the light as if it were the reflecting surface of a dull mirror. If so, the mineral has cleavage, but the cleavage surface consists of several discontinuous parallel planes minutely separated, and rather than perfect cleavage, it has good, fair, or poor cleavage. As will be noted in the discussion of crystal form, it is important to differentiate between cleavage surfaces and crystal faces (the actual breaking of a mineral crystal may be useful in making this differentiation).

In assigning the number of cleavage planes to a specimen, do not make the mistake of calling two parallel planes bounding the opposite sides of a specimen two cleavage planes. In this case the specimen has two cleavage surfaces but only one plane of cleavage, that is, one direction of cleavage (fig 1.3). Halite has cubic cleavage, thus six sides, but only three planes of cleavage because the six sides are made up of three parallel pairs of cleavage surfaces.

The angle at which two cleavage planes intersect is diagnostic. This angle can be determined by inspection. In most cases, you will need to know whether the angle is 90 degrees, almost 90 degrees, or more or less than 90 degrees. The cleavage relationships that you will encounter during the course of your study of common minerals are tabulated for convenience in figure 1.4.

Minerals may exhibit the characteristic of **parting,** sometimes called false cleavage. Parting occurs along planes of weakness in the mineral, but usually the planes are more widely separated and often are due to twinning deformation or inclusions. Parting is not present in all specimens of a given mineral.

Some minerals—quartz is a common example—have no cleavage but show **fracture** that forms a surface with no relationship to the internal structure of the mineral: that is, the break occurs in a direction other than a cleavage plane. The mineral is characterized by **conchoidal** fracture (the fracture surface is curved and smooth and exhibits fine concentric ridges). The mineral asbestos (crysotile) is characterized by **fibrous** fracture. Other descriptive terms often used to describe fracture types include **hackly, uneven** (rough), **even** (smooth), and **earthy** (dull but smooth fracture surfaces common in soft mineral aggregates such as kaolinite).

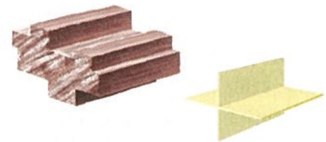
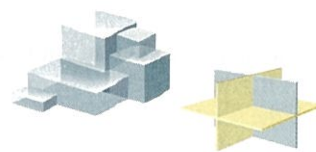
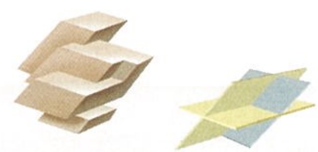
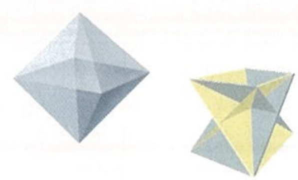
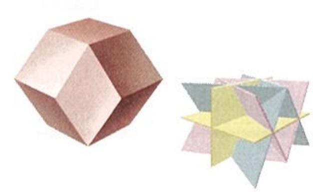
Number of Cleavage Planes	Remarks	Examples
1	**Usually called *basal cleavage.*** Examples: muscovite and biotite.	
2	**Two at 90 degrees.** Examples: feldspar and pyroxene (augite) have cleavage surfaces that intersect at close to 90 degrees.	
2	**Two *not* at 90 degrees.** Example: amphibole (hornblende) has cleavage surfaces that intersect at angles of about 60 and 120 degrees.	
3	**Three at 90 degrees. Minerals with three planes of cleavage that intersect at 90 degrees are said to have *cubic cleavage.*** Examples: halite and galena.	
3	**Three *not* at 90 degrees. A mineral that breaks into a six-sided prism, with each side having the shape of a parallellogram, has *rhombic cleavage.*** Example: calcite.	
4	**Four sets of cleavage surfaces in the form of an octahedron produce *octahedral cleavage.*** Example: fluorite.	
6	**Complex geometric forms.** Example: sphalerite.	

Figure 1.4

Descriptive notes on cleavage planes.

Streak

The color of a mineral's powder is its **streak.** The streak is determined by rubbing the hand specimen on a piece of unglazed porcelain **(streak plate).** Some minerals have a streak that is the same as the color of the hand specimen; others have a streak that differs in color from the hand specimen. The streak of minerals with a metallic luster is especially diagnostic.

Specific Gravity

The **specific gravity** (G) of a mineral is a number that represents the ratio of the mineral's weight to the weight of an equal volume of water. In contrast to density, defined as mass per unit volume, specific gravity is a dimensionless number. The higher the specific gravity, the greater the density of a mineral.

For purposes of determining the specific gravity of the minerals in the laboratory, it is sufficient to utilize a simple "heft" test by lifting the hand specimens. Compare the heft of two specimens of about the same size but of contrasting specific gravity. For example, heft a specimen of graphite (G = 2.2) in one hand while hefting a similarly sized specimen of galena (G = 7.6) in the other. **Take care to compare only similar-sized samples.** This allows you to determine the relative specific gravity of minerals. Minerals such as graphite (G = 2.2) and gypsum (G = 2.3) are relatively light when hefted. Quartz (G = 2.65) and calcite (G = 2.7) are of average heft, whereas corundum (G = 4.0), magnetite (G = 5.2), and galena (G = 7.6) are heavy when hefted.

Diaphaneity

The ability of a mineral to transmit light is its **diaphaneity.** If a mineral transmits light freely so that an object viewed through it is clearly outlined, the mineral is said to be **transparent.** If light passes through the mineral but the object viewed is not clearly outlined, the mineral is **translucent.** Some minerals are transparent in thin slices and translucent in thicker sections. If a mineral allows no light to pass through it, even in the thinnest slices, it is said to be **opaque.**

Tenacity

Tenacity is an index of a mineral's resistance to being broken or bent. It is not to be confused with hardness. Some of the terms used to describe tenacity are

Brittle—The mineral shatters when struck with a hammer or dropped on a hard surface.

Elastic—The mineral bends without breaking and returns to the original shape when stress is released.

Flexible—The mineral bends without breaking but does not return to its original shape when the stress is released.

Crystal Form

A **crystal** is a solid bounded by surfaces (crystal faces) that reflect the internal (atomic) structure of the mineral. **Crystal form** refers to the assemblage of crystal faces that constitute the exterior surface of the crystal. **Crystal symmetry** is the geometric relationship between the faces.

Symmetry in a crystal is determined by completing a few geometric operations. For example, a cube has six faces, each at right angles to the adjacent faces. A planar surface that divides the cube into portions such that the faces on one side of the plane are mirror images of the faces on the other side of the plane is called a **plane of symmetry.** A cube has nine such planes of symmetry. In the same way, imagine a line (axis) connecting the center of one face on a cube with the center of the face opposite it (see cubic model at the top left of fig. 1.5). Rotation of the cube about this axis will show that during a complete rotation a crystal face identical with the first face observed will appear in the same position four times. This is a fourfold **axis of symmetry.** Rotation of the cube around an axis connecting opposite corners will show that three times during a complete rotation an identical face appears, thus a **threefold axis of symmetry.**

The same mineral always shows the same angular relations between crystal faces, a relationship known as the **law of constancy of interfacial angles.** The symmetric relationship of crystal faces, related to the constancy of interfacial angles, is the basis for the recognition of the six crystal systems by crystallographers, and all crystalline substances crystallize in one of the six crystal systems (fig. 1.5). Some common substances, such as glass, are often described as crystalline, but in reality they are **amorphous**—they have solidified with no fixed or regular internal atomic structure.

The six crystal systems can be recognized by the symmetry they display. Figure 1.5 summarizes the basic elements of symmetry for each system and shows some examples of the **crystal habit** (the crystal form commonly taken by a given mineral) of some minerals you may see in the laboratory or a museum.

Perfect crystals usually form under special conditions in which there is open space for them to grow unrestricted during crystallization. In nature, they are the exception rather than the rule. Crystals are more commonly distorted, and their external form (crystal habit) is not perfectly developed. Regardless of the external form, the internal arrangement of the atoms within the crystals is fixed.

Many of the hand specimens you see in the laboratory will be made up of many minute crystals, so few crystal faces, or none, can be seen, and the specimen will appear granular. Other hand specimens may be fragments of larger crystals, so only one or two imperfect crystal faces can be recognized. Although perfect crystals are rare, most student laboratory collections contain some reasonably good crystals of quartz, calcite, gypsum, fluorite, and pyrite.

A word of caution: Cleavage fragments of minerals such as halite, calcite, and galena are often mistaken for crystals. This is because their cleavage fragments have the same geometric form as the crystal.

Two or more crystals of some minerals may be grown together in such a way that the individual parts are related through their internal structures. The external form that results is manifested in a **twinned crystal.** Some twins

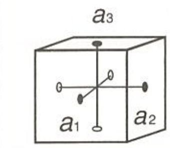
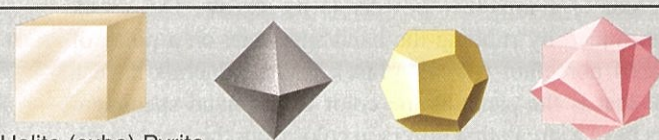
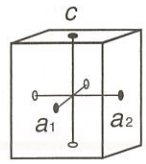
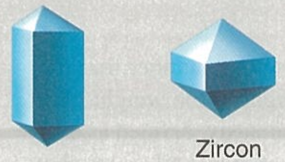
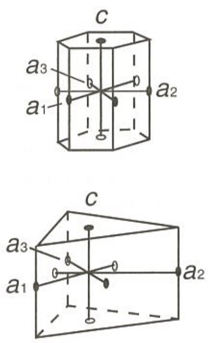
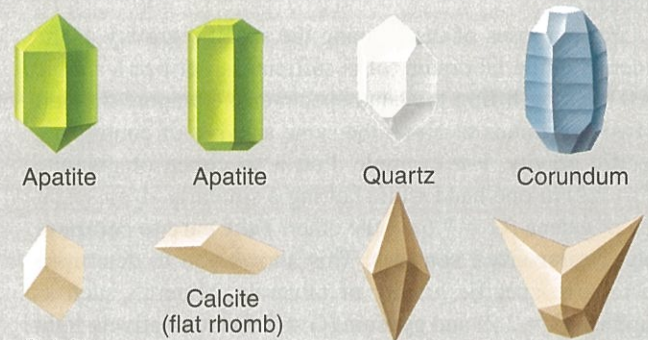
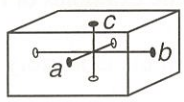
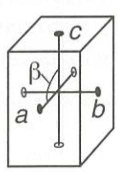
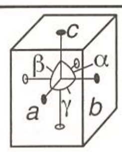
CRYSTAL SYSTEM	CHARACTERISTICS	EXAMPLES*
 CUBIC (ISOMETRIC)	Three mutually perpendicular axes, all of the same length ($a_1 = a_2 = a_3$). Fourfold axis of symmetry around a_1, a_2, and a_3.	 Halite (cube) Pyrite Fluorite Galena; Magnetite (octahedron); Pyrite; Fluorite (twinned)
 TETRAGONAL	Three mutually perpendicular axes, two of the same length ($a_1 = a_2$) and a third (c) of a length not equal to the other two. Fourfold axis of symmetry around c.	 Zircon; Zircon
 HEXAGONAL	Three horizontal axes of the same length ($a_1 = a_2 = a_3$) and intersecting at 120 degrees. The fourth axis (c) is perpendicular to the other three. Sixfold or threefold axis of symmetry around c.	 Apatite; Apatite; Quartz; Corundum; Calcite (steep rhomb); Calcite (flat rhomb); Calcite (scalenohedron); Calcite (twinned)
 ORTHORHOMBIC	Three mutually perpendicular axes of different length. ($a \neq b \neq c$). Twofold axis of symmetry around a, b, and c.	 Topaz; Staurolite** (twinned)
 MONOCLINIC	Two mutually perpendicular axes (b and c) of any length. A third axis (a) at an oblique angle (β) to the plane of the other two. Twofold axis of symmetry around b.	 Orthoclase; Orthoclase (carlsbad twin); Gypsum; Gypsum (twinned)
 TRICLINIC	Three axes at oblique angles (α, β, and γ), all of unequal length. No rotational symmetry.	 Plagioclase

Figure 1.5

Characteristics of the six crystal systems and some examples.

*Colors have been added to the original and are not accurate. They are shown for illustrative purposes only. *Most laboratory collections of minerals for individual student use do not include crystals of these minerals. The collection may, however, contain incomplete single crystals, fragments of single crystals, or aggregates of crystals of one or more minerals. The best examples of these and other crystals may be seen on display in most mineralogical museums. **Staurolite is actually monoclinic but is also classified as pseudo-orthorhombic. Pseudo-orthorhombic means that staurolite appears to be orthorhombic because the angle β in the monoclinic system (see left-hand column under monoclinic) is so close to 90 degrees that in hand specimens it is not possible to discern that the angle β for staurolite is actually 89 degrees, 57 minutes.*

appear to have grown side by side (plagioclase), some are reversed or are mirror images (calcite), and others appear to have penetrated one another (fluorite, orthoclase, staurolite). Recognition of twinned crystals may be useful in mineral identification.

Special Properties

Magnetism

The test for **magnetism,** the permanent magnetic effect of naturally magnetic rocks, requires the use of a common magnet or magnetized knife blade. Usually, magnetite is the only mineral in your collection that will be attracted by a magnet.

Double Refraction (Birefringence)

If an object appears to be double when viewed through a transparent mineral, the mineral is said to have **double refraction.** Calcite is the best common example (see fig. 1.14).

Taste

The saline **taste** of halite is an easy means of identifying the mineral. Few minerals are soluble enough to possess this property. (For obvious sanitary reasons, do not use the taste test on your laboratory hand specimens.)

Odor

Some common minerals have a characteristic **odor** (smell) associated with them. Exhaling your breath on a kaolinite specimen will dampen the surface, causing the mineral to exude a musty or damp earthy odor. The streak of sphalerite will give off a "rotten egg" odor.

Feel

The **feel** of a mineral is the impression gained by handling or rubbing it. Terms used to describe feel are common descriptive adjectives such as **soapy, greasy, smooth, rough,** and so forth.

Chemical Reaction

Calcite will effervesce (bubble) when treated with cold dilute (1N) hydrochloric acid ($CaCO_3 + 2HCl \leftrightarrow CaCl_2 + CO_2 \uparrow + H_2O$). This **chemical reaction** is one example of many that occur in nature. (NOTE): Your laboratory instructor will provide the proper dilute acid if you are to use this test.

Web Connections

Minerals

http://minerals.er.usgs.gov/minerals/

Statistics and information on the worldwide supply, demand, and flow of minerals and materials essential to the U.S. economy, the national security, and protection of the environment.

http://web.wt.net/~daba/Mineral/

A mineralogy database in HTML format. Information on crystallography, chemical composition, physical and optical properties, classification, and alphabetical listings of over 3,800 minerals. Links to other sources of mineralogy data are available at this site.

http://un2sg4.unige.ch/athena/mineral/mineral.html

Mineral lists of IMA-approved mineral names and varieties names. Classification, crystal system, and so forth and some images are also included.

http://mineral.galleries.com/

A collection of mineral descriptions, images, and specimens, continuously updated. Minerals are listed by name, class, and interesting groupings such as gemstones, and there is a system of keyword searching for mineral identification.

http://www.uni-wuerzburg.de/mineralogie/links.html

A source of links on the Internet to a wide variety of mineralogical and geologic sites that may be of interest to mineralogists. The subjects are quite broad and should be of interest to all geologists.

http://www.iumsc.indiana.edu/crystmin.html

An explanation of the cubic crystal system and some of the classes within it. Allows students to rotate applets to see symmetry elements and location in various forms.

Name
Section Date

Identification of Common Minerals

Your instructor will provide you with a variety of minerals to be identified. Take time to examine the minerals and review the various physical properties described in the previous pages. Select several samples and examine them for luster, color, hardness, and streak, and compare their specific gravity (G) using the heft test.

Study table 1.2. Note that certain minerals have physical properties that make their identification relatively easy. For example, graphite is soft, feels greasy, and marks both your hands and paper. Galena is "heavy," shiny, and has perfect cubic cleavage. Calcite has perfect rhombohedral cleavage, is easily scratched by a knife, reacts with cold dilute HCl, and in transparent specimens shows double refraction.

When you feel that you have an understanding of the various physical properties and the tests that you must apply to determine these properties, select a specimen at random from the group of minerals provided to you in the laboratory. Refer to figures 1.6 through 1.21 as an aid to identification. Be aware that your laboratory collection may contain some minerals that are not shown in the figures. Due to the normal variations within a single mineral species, some of the specimens may appear different from the same minerals shown in the figures in this manual.

Identification of the minerals listed in table 1.2 follows an indentification scheme based on the sequential identification of luster, color, hardness, and cleavage.

Using the worksheets provided on the following pages to record your observations, follow the steps outlined as follows.

1. Carefully examine a single mineral specimen selected at random from the group of minerals provided to you in the laboratory.
2. Determine whether the sample has a metallic or nonmetallic luster. Then determine whether it is light- or dark-colored. (The terms *dark* and *light* are subjective. A mineral that is "dark" to one observer may be "light" to another. This possibility is anticipated in table 1.2, where mineral specimens that could fall into either the "light" or "dark" categories are listed in both groups. The same is true for minerals that may exhibit either metallic or nonmetallic luster.)
3. If the mineral falls into either group I or II, proceed to test it first for hardness and then for cleavage. This will place the mineral with a small group of other minerals in table 1.2. Identification can be completed by noting other diagnostic general or specific physical properties.

   If the mineral falls into group III, test it for streak and note other general and specific properties such as color, hardness, cleavage, and so on, until the mineral fits the description of one of those given in table 1.2 under group III.
4. To assist you in confirming your identification, refer to the expanded mineral descriptions in table 1.3.
5. Your laboratory instructor will advise you as to the procedure to be used to verify your identification.
6. Refer to table 1.3 to learn about occurrence, economic value, and uses of each mineral. The chemical groupings and composition of some of the common minerals are presented in table 1.4.

Name *Section* *Date*

Worksheet for Minerals

Sample #	Luster	Color Light/Dark	Hardness	Cleavage Angles	Streak	Special Properties?	Mineral Name	Chemical Composition

Name ______________________ Section ______________________ Date ______________________

Worksheet for Minerals

Sample #	Luster	Color Light/Dark	Hardness	Cleavage Angles	Streak	Special Properties?	Mineral Name	Chemical Composition

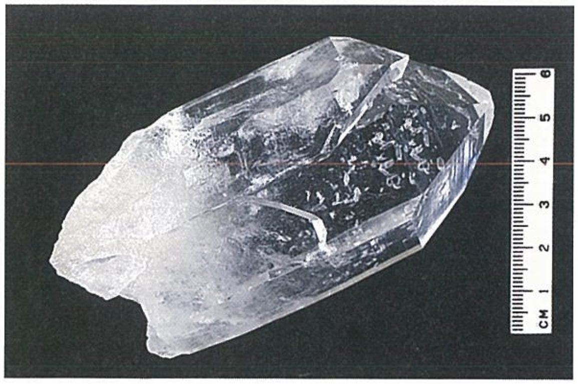


Figure 1.6 Quartz (Rock crystal).

Figure 1.7 Rose quartz.

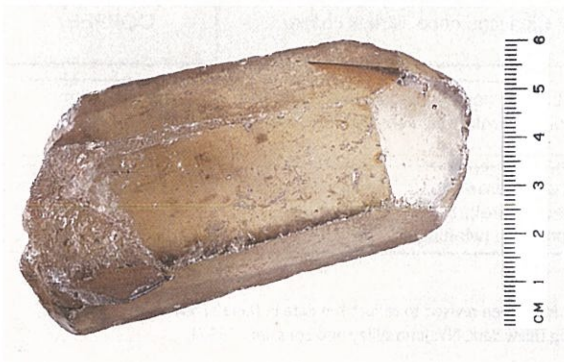


Figure 1.8 Smoky quartz (crystal).

Figure 1.9 Chalcedony (Chert).

Figure 1.10 K-feldspar.

Figure 1.11 Plagioclase.

Figure 1.12 Gypsum (Selenite crystal).

Figure 1.13 Talc.

Table 1.2	Simplified Mineral Identification Key *(Continued)*		
III. Metallic luster	Black, green-black or dark green streak	Metallic luster. Color black. Hardness 5.5–6.0. Cleavage none. Streak black. G = 5.2. Strongly magnetic.	MAGNETITE
		Metallic luster. Color dark gray to black. Hardness 1.0. Perfect basal cleavage. Streak black. G = 2.1–2.2. Greasy feel, smudges fingers when handled.	GRAPHITE
		Metallic luster. Color brass-yellow. Hardness 6.0–6.5. Cleavage none. Streak greenish or brownish black. G = 4.8–5.0. Cubic crystals with striated faces common. *"Fool's gold."*	PYRITE
		Metallic luster. Color brass-yellow, often tarnished to bronze or purple. Hardness 3.5–4.0. Cleavage none. Streak greenish black. G = 4.1–4.3. Usually massive.	CHALCOPYRITE
		Bright metallic luster. Color shiny lead-gray. Hardness 2.5. Perfect cubic cleavage. Streak lead-gray. G = 7.6. Cleavage, high G, and softness diagnostic.	GALENA
	Red streak	Metallic luster. Color steel-gray. Hardness 5.0–6.0. Cleavage none. Streak red to red-brown. G = 5.3. Often micaceous or foliated. Brittle.	HEMATITE (Specularite)
		Metallic luster. Color copper. Hardness 3.0–3.5. Cleavage none. Streak copper. G = 8.8–8.9. Malleable.	COPPER
	Yellow, brown, or white streak	Metallic to dull luster. Color yellow-brown to dark brown, may be almost black. Hardness 5.0–5.5. Cleavage perfect parallel to side pinacoid. Streak brownish yellow to orange-yellow. G = 4.3. Brittle.	GOETHITE (Limonite)
		Submetallic to resinous luster. Color yellow to yellow-brown to dark brown. Hardness 3.5–4.0. Perfect cleavage in six directions (dodecahedral). Streak brown to light yellow to white. G = 3.9–4.1. Cleavage faces common; twinning common.	SPHALERITE

Note: Values for hardness and specific gravity have in most cases been rounded to the nearest tenth and have been revised to reflect the data in *Dana's New Mineralogy*, 8th ed., by Richard V. Gaines, H. Catherine W. Skinner, Eugene E. Foord, Bryan Mason, and Abraham Rosenzweig (New York, NY: John Wiley and Sons, Inc., 1997).

Table 1.2 Simplified Mineral Identification Key *(Continued)*

II. Nonmetallic, dark-colored	Hard (scratches glass)	Shows cleavage	Vitreous luster. Color dark green to black. Hardness 5.5–6.0. Cleavage two planes at nearly 90 degrees. Streak white to gray. G = 3.2–3.6. May exhibit parting.	AUGITE
			Vitreous luster. Color dark green to black. Hardness 5.0–6.0. Cleavage two planes with intersections at 56 and 124 degrees. Streak white to gray. G = 3.0–3.5. Six-sided crystals common.	HORNBLENDE
			Vitreous luster. Color varies from white, gray, to reddish or reddish brown. Hardness 6.0–6.5. Cleavage two planes at nearly 90 degrees. Striations on cleavage planes. Streak white. G = 2.6–2.8. Some forms exhibit play of colors on cleavage surfaces.	PLAGIOCLASE
			Vitreous to dull luster. Color brown to gray-brown. Hardness 7.0. Cleavage fair. Streak gray. G = 3.7–3.8. Characterized by prismatic crystals sometimes forming twins in the shape of crosses.	STAUROLITE
		No cleavage	Vitreous luster. Color varies but commonly brown. Hardness 9.0. Cleavage none. G = 4.0. Barrel-shaped hexagonal crystals with striations on basal faces common.	CORUNDUM
			Vitreous to resinous luster. Color varies but dark red to reddish brown common. Hardness 7.0–7.5. Cleavage none. Streak white or shade of the mineral color. G = 3.4–4.2. Fracture may resemble a poor cleavage. Brittle.	GARNET
			Vitreous luster. Color commonly olive-green, sometimes yellowish. Hardness 6.5–7.0. Cleavage indistinct. Streak white or gray. G = 3.2–4.4. Commonly in granular masses.	OLIVINE
			Vitreous luster. Color gray to gray-black. Hardness 7.0. Cleavage none. Streak white. G = 2.65. Conchoidal fracture. Crystals common; also a variety of massive forms.	QUARTZ
			Waxy to dull luster. Color red to red-brown or brown. Hardness 7.0. Cleavage none. Streak white to gray. G = 2.6.	CHALCEDONY (Jasper)
			Waxy or dull luster. Color dark gray to black. Hardness 7.0. Cleavage none. Streak white. G = 2.6. Characterized by conchoidal fracture with sharp edges.	CHALCEDONY (Flint/Chert)
			Vitreous luster. Color green to black. Hardness 7.0–7.5. Cleavage none. Streak white. G = 3.0–3.2. Characterized by elongated transparent striated prisms with triangular cross sections.	TOURMALINE
	Soft (does not scratch glass)	Shows cleavage	Vitreous to pearly luster. Color dark green, brown, to black. Hardness 2.5–3.0. Perfect basal cleavage forming thin elastic sheets. Streak white to gray. G = 2.7–3.4.	BIOTITE
			Resinous luster. Color yellow-brown to dark brown. Hardness 3.5–4.0. Cleavage perfect in six directions (dodecahedral). Streak brown to light yellow or white. G = 3.9–4.1. Cleavage faces common; twinning common.	SPHALERITE
			Vitreous to earthy luster. Color green to greenish black. Hardness 2.0–3.0. Perfect basal cleavage forming flexible nonelastic sheets. Streak white to pale green. G = 2.3–3.3. May have slippery feel.	CHLORITE
			Vitreous luster. Colorless but wide range of colors possible. Hardness 4.0. Perfect octahedral cleavage (4 planes). Streak white. G = 3.2.	FLUORITE
		No cleavage	Submetallic to earthy luster. Color red to red-brown. Hardness 5.0–6.0 but apparent may be as low as 1. Cleavage none. Streak red. G = 5.0–5.3. Earthy appearance.	HEMATITE "Soft Iron Ore"
			Vitreous to subresinous luster. Color varies; green, blue, brown, purple. Hardness 5.0. Cleavage poor basal. Streak white. G = 3.1–3.2. Crystals common.	APATITE
			Earthy luster. Color varies; yellow, yellow-brown to brownish black. Apparent hardness 1.0. No cleavage apparent to earthy masses. Streak brownish yellow to orange-yellow. G = 3.3–4.3. Earthy masses.	GOETHITE (Limonite)

Table 1.2 Simplified Mineral Identification Key

Group	Hardness	Cleavage	Properties	Mineral
I. Nonmetallic, light-colored	Hard (scratches glass)	Shows cleavage	Vitreous luster. Color varies from white or cream to pink. Hardness 6.0. Cleavage two planes at nearly 90 degrees. Cleavage planes usually show muscle fiber appearance. Streak white. G = 2.6. Crystals common. Grains have glossy appearance.	K-FELDSPAR (Orthocase, Sanidine, Microcline)
			Vitreous luster. Color varies from white to gray or reddish to reddish brown. Hardness 6.0–6.5. Cleavage two planes at nearly 90 degrees. Cleavage planes show striations. Streak white. G = 2.6–2.8. Striations diagnostic. Some samples may show a play of colors.	PLAGIOCLASE
			Vitreous luster. Color white, gray, or pale brown. Hardness 6.0–7.0. Cleavage good in one direction. G = 3.2. Characterized by slim elongated crystals in parallel or subparallel alignment.	SILLIMANITE
			Vitreous luster. Color pale to dark green to yellow green. Hardness 6.0–7.0. Cleavage poor. Streak white. G = 3.3–3.5. Commonly in granular masses of striated prisms.	EPIDOTE
		No cleavage	Vitreous luster. Colorless or white, but almost any color can occur. Hardness 7.0. Cleavage none. Conchoidal fracture. Streak white. G = 2.65. Hexagonal crystals with striations perpendicular to the long dimension of the crystal common. Also massive.	QUARTZ
			Waxy or dull luster. Color varies from white to pale yellow, brown, or gray. Hardness 7.0. Cleavage none. Streak white. G = 2.6. Characterized by conchoidal fracture with sharp edges.	CHALCEDONY (Flint/Chert)
			Waxy luster. Variegated banded colors. Hardness 7.0. Cleavage none. Streak white G = 2.6.	CHALCEDONY (Agate)
			Vitreous luster. Color commonly olive-green, sometimes yellowish. Hardness 6.5–7.0. Cleavage indistinct. Streak white to gray. G = 3.2–4.4. Commonly in granular masses.	OLIVINE
			Vitreous luster. Color green, yellow, pink, blue. Hardness 7.0–7.5. Cleavage none. Streak white. G = 3.0–3.2. Characterized by elongated transparent striated prisms with triangular cross sections.	TOURMALINE
	Soft (does not scratch glass)	Shows cleavage	Vitreous luster. Colorless, also white, gray, yellow, or red. Hardness 2.5. Perfect cubic cleavage. Streak white. G = 2.2. Table salt taste.	HALITE
			Vitreous luster. Colorless and transparent, white, variety of colors possible. Hardness 3.0. Perfect rhombohedral cleavage. Streak white to gray. G = 3.0. Effervesces in cold dilute HCl; double refraction in transparent varieties.	CALCITE
			Vitreous to pearly luster. Colorless, white, pink, gray, greenish, or yellow-brown. Hardness 3.5–4.0. Rhombohedral cleavage. Streak white. G = 2.9–3.0. Crystals common, twinning common. Reaction with cold dilute HCl only when powdered.	DOLOMITE
			Vitreous to pearly luster. Colorless to white, gray, yellowish orange, or light brown. Hardness 2.0. Cleavage good in one direction producing thin sheets. Fracture may be fibrous. Streak white. G = 2.3. Crystals common, twinning common.	GYPSUM (Selenite)
			Pearly to greasy to dull luster. Color usually pale green, also shades of white or gray. Hardness 1.0. Perfect basal cleavage. Streak white. G = 2.6–2.8. Soapy feel.	TALC
			Vitreous to silky or pearly luster. Colorless to shades of green, gray, or brown. Hardness 2.5–3.5. Perfect basal cleavage yielding thin flexible and elastic sheets. Streak white. G = 2.8–2.9.	MUSCOVITE
			Greasy waxlike to silky luster. Color varies, shades of green most common. Hardness 2.0–3.0. Cleavage imperfect. Fibrous parting. Streak white. G = 2.5–2.6.	ASBESTOS (Chrysotile)
			Vitreous luster. Colorless but wide range of colors possible. Hardness 4.0. Perfect octahedral cleavage (4 planes). Streak white. G = 3.2.	FLUORITE
		No cleavage	Dull to earthy luster. Color white, often stained. Hardness 2.0–2.5. No cleavage apparent in common massive varieties. Streak white. G = 2.6–2.7. Earthy smell when damp.	KAOLINITE
			Pearly to greasy or dull luster. Color pale green or shades of gray. Hardness 1.0. No apparent cleavage in massive varieties. Streak white. G = 2.6–2.8. Soapy feel.	TALC
			Earthy luster. White or various colors. Hardness 3.0, may be less. No apparent cleavage in massive varieties. Streak white, G = 3.0. Effervesces in cold dilute HCl.	CALCITE
			Earthy luster. White or various colors. Hardness 3.5–4.0, but apparent may be less. No apparent cleavage. Streak white. G = 2.9–3.0. Reacts with cold dilute HCl only when powdered.	DOLOMITE
			Earthy luster. White color. Hardness 2.0, but apparent may be less. No apparent cleavage in massive varieties. Streak white. G = 2.3. Massive fine-grained variety called *alabaster*, fibrous variety called *satin spar.*	GYPSUM (Alabaster) (Satin Spar)
			Vitreous luster. Color yellow. Hardness 1.5–2.5. Cleavage poor; brittle fracture. Streak pale yellow. G = 1.5–2.5.	SULFUR

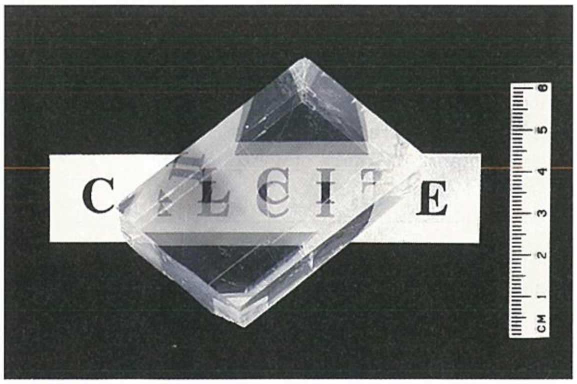


Figure 1.14 Calcite. (Note double refraction.)

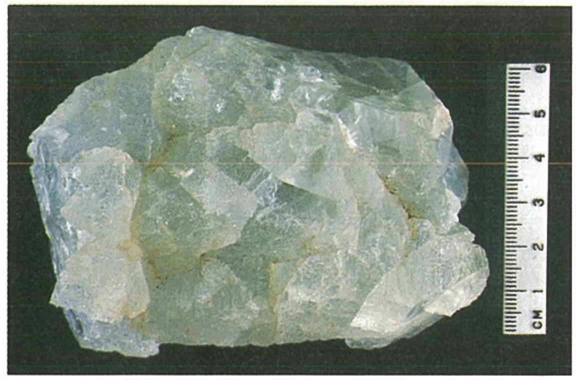


Figure 1.15 Fluorite.

Figure 1.16 Biotite.

Figure 1.17 Olivine.

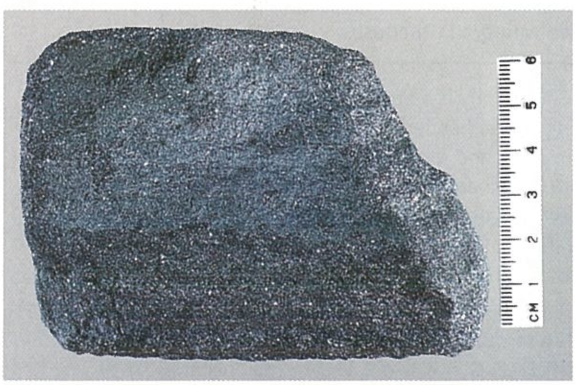


Figure 1.18 Hematite (Specularite).

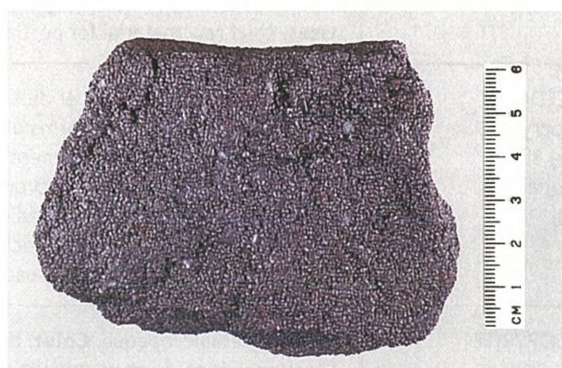


Figure 1.19 Hematite.

Figure 1.20 Goethite (Limonite).

Figure 1.21 Pyrite (crystals).

Table 1.3	Mineral Catalog
APATITE Ca, F Phosphate Hexagonal	**Luster:** nonmetallic; vitreous to subresinous. **Color:** varies, greenish yellow, blue, green, brown, purple, white. **Hardness:** 5.0. **Cleavage:** poor basal; fracture conchoidal. **Streak:** white. **G** = 3.1–3.2. **Habit:** crystals common. Also, massive or granular forms. **Uses:** important source of phosphorus for fertilizers, phosphoric acid, detergents, and munitions.
ASBESTOS (Fiberous Serpentine) Mg, Al Silicate Monoclinic	**Luster:** nonmetallic; greasy or waxlike in massive varieties, silky when fibrous. **Color:** varies, shades of green most common. **Hardness:** 2.0–3.0. **Cleavage:** none. **Streak:** white. **G** = 2.5–2.6. **Habit:** occurs in massive, platy, and fibrous forms. **Uses:** wide industrial uses, especially in roofing and fire-resistant materials.
AUGITE Ca, Mg, Fe, Al Silicate Monoclinic	**Luster:** nonmetallic; vitreous. **Color:** dark green to black. **Hardness:** 5.5–6.0. **Cleavage:** good, two planes at nearly 90 degrees; may exhibit well-developed parting. **Streak:** white to gray. **G** = 3.2–3.6. **Habit:** short, stubby eight-sided prismatic crystals. Often in granular crystalline masses. Most important ferromagnesium mineral in dark igneous rocks. **Uses:** no commercial value. *NOTE:* The *pyroxene* group of minerals contains over 15 members. Augite is an example of the monoclinic members of this group.
BIOTITE K, Mg, Fe, Al Silicate Monoclinic	**Luster:** nonmetallic; vitreous to pearly. **Color:** dark green, brown, or black. **Hardness:** 2.5–3.0. **Cleavage:** perfect basal forming elastic sheets. **Streak:** white to gray. **G** = 2.7–3.4. **Habit:** crystals common as pseudohexagonal prisms, more commonly in sheets or granular crystalline masses. Common accessory mineral in igneous rocks, also important in some metamorphic rocks. **Uses:** commercial value as insulator and in electrical devices.
CALCITE $CaCO_3$ Hexagonal	**Luster:** nonmetallic; vitreous (may appear earthy in fine-grained massive forms). **Color:** colorless and transparent or white when pure; wide range of colors possible. **Hardness:** 3.0. **Cleavage:** perfect rhombohedral. **Streak:** white to gray. **G** = 2.7. **Habit:** crystals common. Also massive, granular, oolitic, or in a variety of other habits. Effervesces in cold dilute HCl. Strong double refraction in transparent varieties. Common and widely distributed rock-forming mineral in sedimentary and metamorphic rocks. **Uses:** chief raw material for portland cement; wide variety of other uses.
CHALCEDONY (Cryptocrystalline Quartz) SiO_2 Hexagonal	**Luster:** nonmetallic; waxy or dull. **Color:** varies. Chalcedony is a group name for a variety of extremely fine-grained, very diverse forms of quartz including *agate,* banded forms; *carnelian* or *sard,* red to brown; *jasper,* opaque and generally red or brown; *chert* and *flint,* massive, opaque and ranging in color from white, pale yellow, brown, gray, to black and characterized by conchoidal fracture with sharp edges; *silicified wood,* reddish or brown showing wood structure. **Hardness:** 7.0. **Cleavage:** none. **Streak:** white. **G** = 2.6. **Habit:** occurs in a wide variety of sedimentary rocks and veins, cavities, or as dripstone. **Uses:** various forms used as semiprecious stones.
CHALCOPYRITE $CuFeS_2$ Hexagonal	**Luster:** metallic, opaque. **Color:** brass-yellow, often tarnished to bronze or purple. **Hardness:** 3.5–4.0. **Cleavage:** none, fracture uneven. **Streak:** greenish black. **G** = 4.1–4.3. **Habit:** may occur as small crystals but usually massive. **Uses:** most important as common copper ore mineral.
CHERT	See Chalcedony
CHLORITE Mg, Fe, Al Silicate Monoclinic	**Luster:** nonmetallic; vitreous to earthy. **Color:** green to green-blue. **Hardness:** 2.5–3.0. **Cleavage:** perfect, basal forming flexible nonelastic sheets. **Streak:** white to pale green. **G** = 2.3–3.3. **Habit:** occurs as foliated masses or small flakes. Common in low-grade schists and as alteration product of other ferromagnesian minerals. **Uses:** no commercial value.
COPPER Cu Cubic (Isometric)	**Luster:** metallic. **Color:** copper. **Hardness:** 3.0–3.5. **Cleavage:** none; fracture hackly; malleable. **Streak:** copper. **G** = 8.8–8.9. **Habit:** distorted cubes and octahedrons; dendritic masses. **Uses:** ore of copper for pipes, electrical wire, coins, ammunition, brass.

Table 1.3	Mineral Catalog *(Continued)*
CORUNDUM Al_2O_3 Hexagonal	**Luster:** nonmetallic, adamantine to vitreous. **Color:** varies; yellow, brown, green, purple; gem varieties blue (sapphire) and red (ruby). **Hardness:** 9.0. **Cleavage:** none, basal parting common with striations on parting planes. **Streak:** white, **G** = 4.0. **Habit:** barrel-shaped crystals common, frequently with deep horizontal striations. **Uses:** wide uses as an abrasive.
DOLOMITE $CaMg(CO_3)_2$ Hexagonal	**Luster:** nonmetallic, vitreous to pearly. **Color:** colorless, white, gray, greenish, yellow-brown; other colors possible. **Hardness:** 3.5–4.0. **Cleavage:** rhombohedral. **Streak:** white. **G** = 2.9–3.0. **Habit:** crystals common. Twinning common. Fine-grained; massive and granular forms common also. Distinguished from calcite by fact that it effervesces in cold dilute HCl only when powdered. Widespread occurrence in sedimentary rocks. **Uses:** variety of industrial uses as flux, as a source of magnesia for refractory bricks, and as a source of magnesium or calcium metal.
EPIDOTE (Group) Complex Silicate Monoclinic	**Luster:** nonmetallic; vitreous. **Color:** pale to dark green to yellow-green. **Hardness:** 6.0–7.0. **Cleavage:** poor; fracture brittle. **Streak:** white. **G** = 3.3–3.5. **Habit:** massive or striated prisms. **Uses:** gemstone.
FLINT/JASPER	See Chalcedony
FLUORITE CaF_2 Cubic (Isometric)	**Luster:** nonmetallic, vitreous transparent to translucent. **Color:** colorless when pure; occurs in a wide variety of colors: yellow, green, blue, purple, brown, and shades in between. **Hardness:** 4.0. **Cleavage:** perfect octahedral (four directions parallel to faces of an octahedron). **Streak:** white. **G** = 3.2. **Habit:** twins fairly common. Common as a vein mineral. **Uses:** industrial use as a flux in steel and aluminum metal smelting; source of fluorine for hydrofluoric acid.
GALENA PbS Cubic (Isometric)	**Luster:** bright metallic. **Color:** lead-gray. **Hardness:** 2.5. **Cleavage:** perfect cubic. **Streak:** lead-gray. **G** = 7.6. **Habit:** crystals common, easily identified by cleavage, high specific gravity, and softness. **Uses:** chief lead ore.
GARNET Fe, Mg, Ca, Al Silicate Cubic (Isometric)	**Luster:** nonmetallic; vitreous to resinous. **Color:** varies but dark red and reddish brown most common; white, pink, yellow, green, black depending on composition. **Hardness:** 7.0–7.5. **Cleavage:** none. **Streak:** white or shade of mineral color. **G** = 3.4–4.2. **Habit:** crystals common. Also in granular masses. **Uses:** some value as an abrasive. Gemstone varieties are pyrope (red) and andradite (green).
GOETHITE (Limonite) FeO (OH) Orthorhombic	**Luster:** varies, crystals adamantine; metallic to dull in masses, fibrous varieties may be silky. **Color:** dark brown, yellow-brown, reddish brown, brownish black, yellow. **Hardness:** 5.0–5.5, but apparent may be as low as 1.0. **Cleavage:** perfect parallel to side pinacoid, fracture uneven. **Streak:** brownish yellow to orange-yellow. **G** = 4.3. **Habit:** crystals uncommon. Usually massive or earthy as residual from chemical weathering, or stalactic by direct precipitation. Often in radiating fibrous forms. This species includes the common brown and yellow-brown ferric oxides collectively called *limonite*. **Uses:** commercial source of iron ore.
GRAPHITE C Hexagonal	**Luster:** metallic to dull. **Color:** dark gray to black. **Hardness:** 1.0. **Cleavage:** perfect basal. **Streak:** black. **G** = 2.1–2.2. **Habit:** characteristic greasy feel, marks easily on paper. Crystals uncommon, usually as foliated masses. Common metamorphic mineral. **Uses:** wide industrial uses due to high melting temperature (3,000°C) and insolubility in acid. Used also as lead in pencils.
GYPSUM $CaSO_4 \cdot 2H_2O$ Monoclinic	**Luster:** nonmetallic; vitreous to pearly; some varieties silky. **Color:** colorless to white, gray, yellowish orange, light brown. **Hardness:** 2.0. **Cleavage:** good in one direction producing thin sheets; fracture conchoidal in one direction, fibrous in another. **Streak:** white. **G** = 2.3. **Habit:** crystals common and simple in habit; twinning common. Varieties include *selenite,* coarsely crystalline, colorless and transparent; *satinspar,* parallel fibrous structure; and *alabaster,* massive fine-grained gypsum. Occurs widely as sedimentary deposits and in many other ways. **Uses:** mined for use in wallboard, plaster, and filler for paper products.

Table 1.3	Mineral Catalog *(Continued)*
HALITE NaCl Cubic (Isometric)	**Luster:** nonmetallic, vitreous. Transparent to translucent. **Color:** colorless, also white, gray, yellow, red. **Hardness:** 2.5. **Cleavage:** perfect cubic. **Streak:** white. **G** = 2.2. **Habit:** crystals common, also massive or coarsely granular. Characteristic taste of table salt. **Uses:** widely used as source of both sodium and chlorine and as salt for table, pottery glaze, and industrial purposes.
HEMATITE Fe_2O_3 Hexagonal	**Luster:** metallic in form known as specularite and in crystals; submetallic to dull in other varieties. **Color:** steel-gray in specularite, dull to bright red in other varieties. **Hardness:** 5.0–6.0, but apparent may be as low as 1.0. **Cleavage:** none; basal parting fracture uneven. **Streak:** red-brown. **G** = 5.3. **Habit:** crystals uncommon. May occur in crystalline, botryoidal, or earthy masses. Specularite commonly micaceous or foliated. **Streak:** characteristic. **Uses:** common iron ore.
HORNBLENDE (Amphibole) Ca, Na, Mg, Fe, Al Silicate Monoclinic	**Luster:** nonmetallic, vitreous. **Color:** dark green, dark brown, black. **Hardness:** 5.0–6.0. **Cleavage:** perfect on two planes meeting at 56° and 124°. **Streak:** gray or pale green. **G** = 3.0–3.5. **Habit:** long, six-sided crystals common. **Color:** usually darker than other minerals in amphibole group. *Tremolite-Actinolite,* also a member of the amphibole group, is lighter in color and commonly is fibrous or asbestiform, may range in color from white to green, and has white streak. **Uses:** no commercial use. *Nephrite,* the amphibole form of jade, is used for jewelry.
KAOLINITE Hydrous Aluminosilicate Triclinic	**Luster:** nonmetallic, dull to earthy. **Color:** white, often stained by impurities to red, brown, or gray. **Hardness:** 2.0–2.5. **Cleavage:** perfect basal but rarely seen because of small grain size. **Streak:** white. **G** = 2.6–2.7. **Habit:** found in earthy masses. Earthy odor when damp. *NOTE:* Kaolinite is used here as an example of the clay minerals. It normally is not possible to distinguish the various clay minerals on the basis of their physical properties. Other clay minerals include *montmorillonite* (smectite), *illite,* and *vermiculite.* **Uses:** kaolinite is used as a paper filler and ceramic; montmorillonite for drilling muds; illite has no industrial use; and vermiculite is mined and processed for use as a lightweight aggregate, potting soils, and as insulation.
K-FELDSPAR (Orthoclase, Sanidine, Microcline) $K(AlSi_3O_8)$ Monoclinic (Orthoclase, Sanidine) Triclinic (Microcline)	**Luster:** nonmetallic, vitreous. **Color:** varies, white, cream, or pink; *sanidine,* the high-temperature variety, is usually colorless. **Hardness:** 6.0. **Cleavage:** two planes at nearly right angles. **Streak:** white. **G** = 2.6. **Habit:** crystals not common. Has glossy appearance. Distinguished from other feldspars by absence of twinning striations. *NOTE: Microcline* variety is triclinic. When light green the color is diagnostic, more commonly white, green, pink. Occurrence helpful; most K-feldspar in pegmatites is microcline. **Uses:** commonly used in ceramics, glassmaking, and scouring and cleansing products.
LIMONITE	See Goethite
MAGNETITE $FeFe_2O_4$ Cubic (Isometric)	**Luster:** metallic. **Color:** black. **Hardness:** 5.5–6.0. **Cleavage:** none, some octahedral parting. **Streak:** black. **G** = 5.2. **Habit:** usually in granular masses. Strongly magnetic, some specimens show polarity (lodestones). Widespread occurrence in a variety of rocks. **Uses:** used commercially as iron ore.
MUSCOVITE K, Al Silicate Monoclinic	**Luster:** nonmetallic, vitreous to silky or pearly. **Color:** colorless to shades of green, gray, or brown. **Hardness:** 2.5–3.5. **Cleavage:** perfect basal yielding thin sheets that are flexible and elastic; may show some parting. **Streak:** white. **G** = 2.8–2.9. **Habit:** usually in small flakes or lamellar masses. Commercial deposits are generally found in granite pegmatites. **Uses:** variety of industrial uses.
OLIVINE $(Mg, Fe)_2SiO_4$ Orthorhombic	**Luster:** nonmetallic, vitreous. **Color:** olive-green to yellowish; nearly pure Mg-rich varieties may be white (forsterite) and nearly pure Fe-rich varieties brown to black (fayalite). **Hardness:** 6.5–7.0. **Cleavage:** indistinct. **Streak:** white or gray. **G** = 3.2–4.4. **Habit:** usually in granular masses. Crystals uncommon. A mineral of basic and ultrabasic rocks. **Uses:** forsterite variety used for refractory bricks.
PLAGIOCLASE Ranges in composition from Albite, $NaAlSi_3O_8$, to Anorthite, $CaAl_2Si_2O_8$ Triclinic	**Luster:** nonmetallic, vitreous. **Color:** white or gray, reddish, or reddish brown. **Hardness:** 6.0–6.5. **Cleavage:** two planes at close to right angles, twinning striations common on basal cleavage surfaces. **Streak:** white. **G** = 2.6–2.8. **Habit:** crystals common for Na-rich varieties, uncommon for intermediate varieties, rare for anorthite. Twinning common. Twinning striations on basal cleavage useful to distinguish from orthoclase. Some varieties show play of colors. **Uses:** sodium-rich varieties mined for use in ceramics.

Table 1.3	Mineral Catalog *(Continued)*
PYRITE FeS_2 Cubic (Isometric)	**Luster:** metallic. **Color:** brass-yellow, may be iridescent if tarnished. **Hardness:** 6.0–6.5. **Cleavage:** none, conchoidal fracture. **Streak:** greenish or brownish black. **G** = 4.8–5.0. **Habit:** crystals common. Usually cubic with striated faces. Crystals may be deformed. Massive granular forms also. Most widespread sulfide mineral. Known as "fool's gold." **Uses:** source of sulfur for sulfuric acid. *NOTE: Marcasite* (FeS_2) is orthorhombic, usually paler in color, and is commonly altered.
QUARTZ SiO_2 Hexagonal	**Luster:** nonmetallic, vitreous. **Color:** typically colorless or white, but almost any color may occur. **Hardness:** 7.0. **Cleavage:** none, conchoidal fracture. **Streak:** white, but difficult to obtain on streak plate. **G** = 2.65. **Habit:** prismatic crystals common with striations perpendicular to the long dimension; also a variety of massive forms. Color variations lead to varieties called smoky quartz, rose quartz, milky quartz, and amethyst. Common mineral in all categories of rocks. **Uses:** wide variety of commercial uses include glassmaking, electronics, and construction products.
SILLIMANITE Al_2SiO_5 Orthorhombic	**Luster:** nonmetallic; vitreous. **Color:** white, gray, or pale brown. **Hardness:** 6.0–7.0. **Cleavage:** good, one direction. **G** = 3.2. **Habit:** slender prisms. **Uses:** high-temperature ceramics.
SPHALERITE ZnS Cubic (Isometric)	**Luster:** usually nonmetallic, some varieties submetallic, most commonly resinous. **Color:** yellow, yellow-brown to dark brown. **Hardness:** 3.5–4.0. **Cleavage:** perfect dodecahedral (six directions at 120 degrees). **Streak:** brown to light yellow or white. **G** = 3.9–4.1. **Habit:** crystals common as distorted tetrahedra or dodecahedra. Twinning common. Also massive or granular. **Uses:** important zinc ore.
STAUROLITE Complex Silicate Monoclinic	**Luster:** nonmetallic. **Color:** brown to gray-brown. **Hardness:** 7.0. **Cleavage:** good, one direction. **G** = 3.7–3.8. **Habit:** prismatic; forms twins in shape of crosses. **Uses:** gemstone crosses called "fairy crosses."
SULFUR S Orthorhombic	**Luster:** nonmetallic; vitreous to earthy. **Color:** yellow. **Hardness:** 1.5–2.5. **Cleavage:** poor; fracture brittle. **G** = 2.1. **Habit:** transparent to translucent crystals; earthy masses. **Uses:** wide industrial uses, especially drugs, sulfuric acid, and insecticides.
TALC Mg Silicate Monoclinic	**Luster:** nonmetallic, pearly to greasy or dull. **Color:** usually pale green, also white to silver-white or gray. **Hardness:** 1.0. **Cleavage:** perfect basal, massive forms show no visible cleavage. **Streak:** white. **G** = 2.6–2.8. Usually foliated masses or dense fine-grained dark gray to green aggregates (soapstone). **Habit:** crystals extremely rare. Soapy feel is diagnostic. **Uses:** commercial uses in paints, ceramics, roofing, paper, and toilet articles.
TOURMALINE Complex Borosilicate Hexagonal	**Luster:** nonmetallic; vitreous. **Color:** black, green, yellow, pink, blue. **Cleavage:** none; fracture brittle. **Hardness:** 7.0–7.5. **G** = 3.0–3.2. **Habit:** elongated opaque to transparent striated prisms with triangular cross sections. **Uses:** gemstone; crystals used in radio transmitters.

Table 1.4 Chemical Grouping and Composition of Some Common Minerals

Chemical Group		Example: Mineral Name	Example: Chemical Formula*†
ELEMENTS		Copper Graphite Diamond Sulfur	Cu C C S
OXIDES		Quartz Hematite Magnetite Goethite (Limonite) Corundum	SiO_2 Fe_2O_3 Fe_3O_4 $FeO(OH)$ Al_2O_3
SULFIDES		Pyrite Chalcopyrite Galena Sphalerite	FeS_2 $CuFeS_2$ PbS ZnS
SULFATES		Anhydrite Gypsum	$CaSO_4$ $CaSO_4 \cdot 2H_2O$
CARBONATES		Calcite Dolomite	$CaCO_3$ $CaMg(CO_3)_2$
PHOSPHATES		Apatite	$Ca_5(PO_4)_3F$
HALIDES		Halite Fluorite	$NaCl$ CaF_2
SILICATES	OLIVINE GROUP	Olivine	$(Mg,Fe)_2SiO_4$
SILICATES	AMPHIBOLE GROUP	Hornblende Asbestos (Fibrous Serpentine)	Ca,Na,Mg,Fe,Al Silicate Mg,Al Silicate
SILICATES	PYROXENE GROUP	Augite	Ca,Mg,Fe,Al Silicate
SILICATES	MICA GROUP	Muscovite Biotite Chlorite Talc Kaolinite	K,Al Silicate K,Mg,Fe,Al Silicate Mg,Fe,Al Silicate Mg Silicate Al Silicate
SILICATES	FELDSPAR GROUP	K-feldspar Plagioclase (Ab, An) Albite (Ab) Anorthite (An)	$K(AlSi_3O_8)$ Mixture of Ab and An $NaAlSi_3O_8$ $CaAl_2Si_2O_8$
SILICATES	GARNET GROUP	Garnet	Fe,Mg,Ca,Al Silicate
SILICATES	ANDALUSITE GROUP	Sillimanite Staurolite	Al_2SiO_5 Hydrated Fe,Mg,Al Silicate
SILICATES	EPIDOTE GROUP	Epidote	Hydrated Ca,Fe,Al Silicate
SILICATES	SILICA GROUP	Quartz	SiO_2
SILICATES	TOURMALINE GROUP	Tourmaline	Hydrated Na,Li,Ca,Fe,Mn,Cr,V

*Some common elements and their symbols:
Al-Aluminum, C-Carbon, Ca-Calcium, Cl-Chlorine, Cu-Copper, F-Fluorine, Fe-Iron, H-Hydrogen, K-Potassium, Mg-Magnesium, Na-Sodium, O-Oxygen, P-Phosphorus, Pb-Lead, S-Sulfur, Si-Silicon, Zn-Zinc

†Chemical formulas from *Mineralogy*, 2d ed., by L.G. Berry, Brian Mason, and R.V. Dietrich (New York, NY: W.H. Freeman, 1983).