# Chapter 3

# Matter and Minerals

*Matter and Minerals* provides a foundation for understanding what minerals are made of, what their properties are, and how minerals are important as rock-forming components and as resources. The chapter begins by outlining the criteria used to define minerals and minerals' relationship to rocks. This is followed by a brief explanation of the chemistry involved in how atoms bond to form minerals. After presenting the various physical properties exhibited by minerals, the chapter introduces the major group of mineral—the silicates. The two major rock-forming silicate mineral groups—the light, nonferromagnesian minerals and the dark, ferromagnesian minerals—are described in some detail, especially as they relate to their occurrence in rocks and to their uses. The final part of the chapter introduces the major nonsilicate minerals and the concept of minerals as nonrenewable resources.

## CHAPTER OUTLINE

**1.** Minerals: Building Blocks of Rocks
   a. Defining a Mineral
      i. Naturally Occurring
      ii. Generally iInorganic
      iii. Solid Substance
      iv. Orderly Crystalline Structure
      v. Definite Chemical Composition That Allows for Some Variation
   b. What Is a Rock?
**2.** Atoms: Building Blocks of Minerals
   a. Properties of Protons, Neutrons, and Electrons
   b. Elements: Defined by Their Number of Protons
**3.** Why Atoms Bond
   a. The Octet Rule and Chemical Bonds
   b. Ionic Bonds: Electrons Transferred
   c. Covalent Bonds: Electron Sharing
   d. Metallic Bonds: Electrons Free to Move
**4.** Properties of Minerals
   a. Optical Properties
      i. Luster
      ii. Color
      iii. Streak
      iv. Ability to Transmit Light
   b. Crystal Shape or Habit
   c. Mineral Strength
      i. Hardness
      ii. Cleavage
      iii. Fracture
      iv. Tenacity

   d. Density and Specific Gravity
   e. Other Properties of Minerals
5. Mineral Groups
   a. Classifying Minerals
   b. Silicate versus Nonsilicate Minerals
6. The Silicates
   a. Silicate Structures
      i. Minerals with Independent Tetrahedrons
      ii. Minerals with Chain or Sheet Structures
      iii. Minerals with Three-Dimensional Frameworks
   b. Joining Silicate Structures
7. Common Silicate Minerals
   a. The Light Silicates
      i. Feldspar Group
      ii. Quartz
      iii. Muscovite
      iv. Clay Minerals
   b. The Dark Silicates
      i. Olivine Group
      ii. Pyroxene Group
      iii. Amphibole Group
      iv. Biotite
      v. Garnet
   c. Important Nonsilicate Minerals
8. Minerals: A Nonrenewable Resource
   a. Renewable versus Nonrenewable Resources
   b. Mineral Resources and Ore Deposits

## FOCUS ON CONCEPTS

Each statement represents the primary learning objective for the corresponding major heading within the chapter. After you complete the chapter, you should be able to:

**3.1** **List** the main characteristics that an Earth material must possess to be considered a mineral and **describe** each.

**3.2** **Compare and contrast** the three primary particles contained in atoms.

**3.3** **Distinguish** among ionic bonds, covalent bonds, and metallic bonds.

**3.4** **List and describe** the properties that are used in mineral identification.

**3.5** **Explain** how minerals are classified and **name** the most abundant mineral group in Earth's crust.

**3.6** **Sketch** the silicon-oxygen tetrahedron and **explain** how these fundamental building blocks join together to form other silicate structures.

**3.7** **Compare and contrast** the light (nonferromagnesian) silicates with the dark (ferromagnesian) silicates and **list** four common minerals from each group.

**3.8** **List** the common nonsilicate minerals and **explain** why each is important.

**3.9** **Discuss** Earth's mineral resources in terms of renewability. **Differentiate** between mineral resources and ore deposits.

## TEACHING STRATEGIES

### "Muddiest Points" – "Points for Clarification"

- Nonscience students may have unfounded fears about learning chemistry in an introductory geology course. However, an understanding of certain basics of chemistry, specifically atomic structure, is vital in order to understand why and how atoms bond to form minerals. Be prepared with visuals, especially stick-and-ball molecular models, if available.
- Understanding the various silicate structure types is another area where visualizations can be helpful. If the students can be put at ease with the basics of atomic structure, they will be more receptive to the concept of the silicate structures.
- Students are usually very responsive to discussions about the use of mineral resources. This can be an energizing topic when aspects of each student's everyday life are related to minerals or mineral-derived products. Bringing aspects of this end-of-chapter topic into the earlier sections on silicate structures can help ease the perceived discomfort of the chemistry basics and maintain student interest throughout the chapter.

### Teaching Tips

**3.2** Utilize as many visuals as possible to introduce basic atomic structure and reinforce the concepts of the typical orbital model of the atom. Hands-on molecular models are always more dynamic than static images, if available.

**3.6 & 3.7** Create silicon-oxygen tetrahedrons by gluing four ping-pong balls with a sphere of colored epoxy as the silicon in the middle. Create some incomplete tetrahedrons by gluing only three ping-pong balls together with a small amount of colored epoxy. Use these as visuals to illustrate how tetrahedrons share oxygen ions during polymerization to form the various structures. While discussing section 3.7, bring in details about some of the economic and industrial uses for some of the silicates, such as the use of muscovite in everything from eye shadow and other cosmetics to cake frosting and candy coating. Also have students start creating lists of silicate minerals that have economic or industrial uses. As preparatory material, assign students to review SmartFigure 3.24 prior to class.

**3.8** While presenting the nonsilicate minerals it will be easy to incorporate the important uses of many of them. As with the silicates, bring in details about the various economic uses in addition to what is referenced in Figure 3.33.

**3.9** By section 3.9, students should be well energized for discussion regarding minerals as economic resources. During this topic, have students begin a small journal, beginning with the list of silicate minerals formed during section 3.7, and add to it weekly with "geologic materials (minerals or mineral-based products) that I interacted with this week." These journal entries can be continued into the topics of igneous and sedimentary rocks as well.

## MasteringGeology and Learning Catalytics resources/ideas/activities

**MasteringGeology** activities that utilize video, interactive animations, and gigapans (high-resolution panoramic images) are effective in giving students preparatory opportunities that are directly correlated with the chapter content. Have students complete MasteringGeology activities in advance of class time to help them learn the material.

- All of the end-of-section Concept Check type items from the MasteringGeology item library are excellent preparatory questions. In addition, especially focus on the following additional items for this chapter:

| Section | Item Type | Title |
|---|---|---|
| 3.1 | Coaching Activities | SmartFigure: Minerals vs. Rocks |
| | Coaching Activities | Give It Some Thought: Identifying Minerals |
| 3.3 | Coaching Activities | Give It Some Thought: Chemical Bonds |
| 3.4 | Coaching Activities | SmartFigure: Mineral Cleavage |
| | Coaching Activities | SmartFigure: Mineral Hardness |
| 3.6 | Coaching Activities | SmartFigure: Silicate Minerals |
| 3.9 | Coaching Activities | My Story Video Quiz–Bolivia: Under the Rich Mountain |

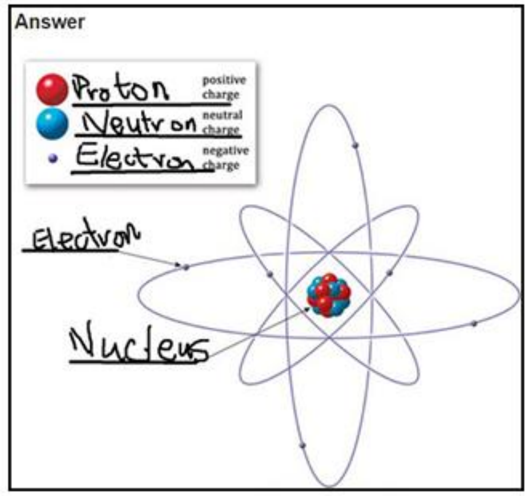
**LearningCatalytics** activities can provide an assessment of students' understanding in real-time to allow opportunities for review or discussion (either in small groups or the entire class).

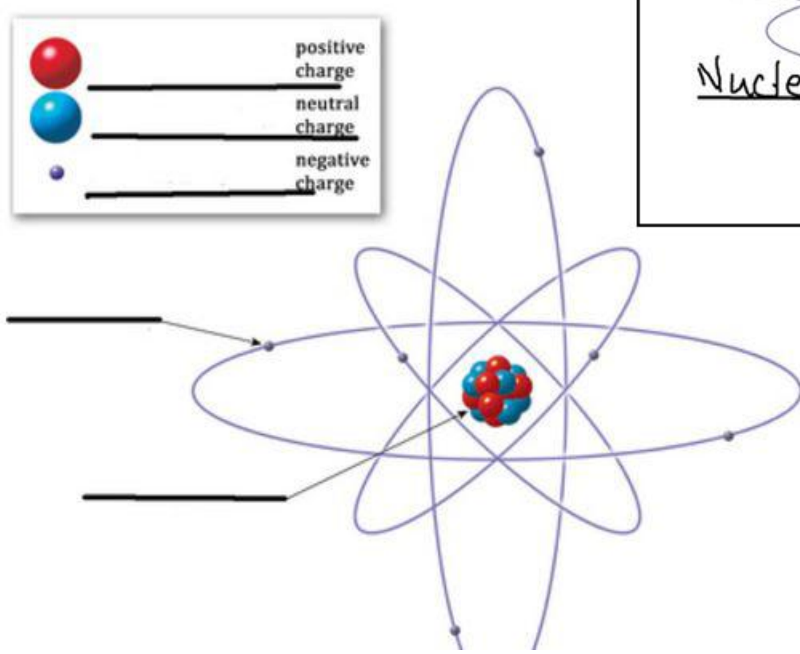
- Using images from the text, query students' understanding of the basic atomic structure. In the LearningCatalytics activity shown below, students answer and name the particles of a basic atomic model by sketching the answer on their mobile device, tablet, or laptop. This could also be a sketch-type item where students sketch and label their own atom structure and all sketches can be displayed for class discussion:

**Question**

Label the following picure by sketching the following terms in the blanks as appropriate:

Terms:
electron
proton
neutron
nucleus



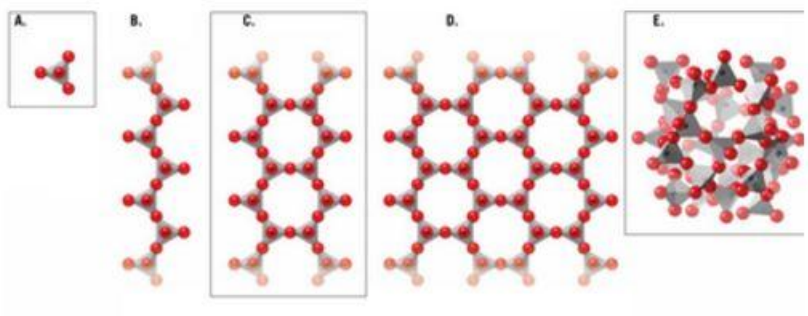



- Using images from the text, query students' understanding of the silicate structure types. In the LearningCatalytics activity shown below, students answer by matching the structure type with the images, answering on their mobile device, tablet, or laptop.

**Question preview**

Match the silicate structure name with its drawing on the diagram




| | |
|---|---|
| A. Isolated tetrahedra | 1. A |
| B. Single Chain | 2. B |
| C. Double Chain | 3. C |
| D. Sheet | 4. D |
| E. 3-D Framework | 5. E |

## TEACHER RESOURCES

**Web Resources:**

- www.webmineral.com and www.mindat.org provide excellent images of molecular structure on their individual mineral pages. Use the search field to find individual minerals.
- Steps to mineral identification: http://geology.about.com/od/mineral_ident/ss/beginminident.htm
- An easy demonstration will help students understand how the silicate tetrahedra is involved in mineral structure: http://serc.carleton.edu/NAGTWorkshops/intro/activities/24296.html
- Smithsonian Department of Mineral Sciences: http://mineralsciences.si.edu/
- State mineral resources: http://minerals.usgs.gov/minerals/pubs/state/

## CONCEPT CHECKS

### 3.1 Minerals: Building Blocks of Rocks

1. The five characteristics a material must have to be considered a mineral are: naturally occurring, generally inorganic, solid, possess an ordered (crystalline) internal structure, and a more or less definite chemical composition.
2. Synthetic diamonds are not classified as minerals because they are not naturally occurring. Wood is not a mineral because it is mostly organic, as opposed to inorganic.

3. A rock is defined as an aggregate of mineral or mineral-like matter that occurs naturally as part of Earth. Rocks differ from minerals in that their definition is not as strict as minerals.

### 3.2 Atoms: Building Blocks of Minerals

1. The three main particles of an atom are the protons, the neutrons, and the electrons. Protons and neutrons have about the same mass, but protons have a positive electrical charge while neutrons are neutral; they have no electrical charge. Electrons are significantly less massive than protons and neutrons, and electrons have a negative electrical charge.
2. The atomic structure sketch should be similar to Figure 3.4 in the text.

### 3.3 Why Atoms Bond

1. Ions are atoms that have an electrical charge (gained or lost valence electrons). Therefore, all ions are atoms, but not all atoms are ions.
2. When an atom loses its valence electrons, it becomes a positive ion. When an atom gains valence electrons, it becomes a negative ion.
3. Ionic bonds are formed when oppositely charged ions attract one another and form an electrically neutral compound. Covalent bonds occur when atoms share their valence electrons between them in an attempt to satisfy the octet rule. In metallic bonding, each atom donates its valence electrons to a common pool of electrons that can be shared among all of the atoms. The electrons are free to roam throughout the sea of positively charge ions.

### 3.4 Properties of a Mineral

1. A mineral's luster is the manner in which light reflects from the mineral's surface.
2. The color of a mineral can be ambiguous or misleading due to even slight impurities that impart a variety of possible colors to the mineral. One such example is quartz, which occurs in a variety of colors related to different impurities.
3. Due to the result of breaking along planes of weak atomic bonding, cleavage produces relatively smooth, flat surfaces. In contrast, fracture occurs when atomic bonds are more equally strong in all directions resulting in a more randomly uneven broken surface.
4. Tenacity describes a mineral's resistance to deformation like breaking, bending, or cutting. Terms that describe mineral tenacity are malleable, sectile, and elastic.
5. The effervescent reaction with cold, dilute hydrochloric acid is the simple test to confirm the identification of the mineral calcite. See SmartFigure 3.21.

### 3.5 Mineral Groups

1. *Rock-forming minerals* are the few dozen abundant minerals that make up most of Earth's crust. *Economic minerals* are the less abundant minerals that society uses extensively in the manufacture of products. Some rock-forming minerals can also be considered economic minerals when present in the proper quantity and geologic setting.
2. The eight most abundant elements in Earth's crust, from most abundant to least abundant, are: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium.

3. A mineral *species* is a collection of minerals that have similar internal structures and chemical compositions. A mineral *variety* is a subdivision of a mineral species where minerals have slightly different properties (usually color) due to substitutions and incorporations of other atoms in the mineral structure.

### 3.6 The Silicates

1. The Si-O tetrahedron sketch should be similar to Figure 3.23 in the text.
2. Independent silicon-oxygen tetrahedra have one silicon atom for every four oxygen atoms, whereas three-dimensional framework tetrahedra have one silicon for every two oxygen atoms. Therefore, three-dimensional framework silicates have relatively twice as much silicon as independent tetrahedra silicates.
3. Quartz is constructed of essentially nothing but silicon-oxygen tetrahedra linked together in a three-dimensional framework. This creates roughly equal-strength atomic bonds in all directions that provide quartz with its hardness, strength, and lack of cleavage. In comparison, talc is constructed of layers (sheets) of silicon-oxygen tetrahedra that are more weakly bonded together with positive magnesium ions. This results in talc easily cleaving between its sheets, which gives it a slippery feel as the sheets slide past each other.

### 3.7 Common Silicate Minerals

1. The main difference between the light and dark silicates is their relative specific gravities (densities); light silicates are less dense (lower specific gravity) than the dark silicates. This difference is mainly due to the amounts of iron and magnesium that are present, with light silicates containing much less iron and magnesium and relatively more potassium, aluminum, and sodium relative to the dark silicates.
2. Muscovite and biotite both have sheet silicate structures and both contain some potassium. However, biotite contains iron and magnesium while muscovite does not. In addition to lacking iron and magnesium, muscovite contains relatively more aluminum than biotite.
3. Color is not a good property to use when distinguishing orthoclase and plagioclase feldspar because both can occur in similar, light-colored varieties. The most effective means of distinguishing them is to look for the presence of *striations* on the cleavage surface of the plagioclase feldspar, as orthoclase will never exhibit that property.

### 3.8 Important Nonsilicate Minerals

1. The six common nonsilicate mineral groups include carbonates [defined by $(CO_3)^{2-}$], halides (defined by $Cl^{1-}$, $F^{1-}$, $Br^{1-}$), oxides (defined by $O^{2-}$), sulfides (defined by $S^{2-}$), sulfates [defined by $(SO_4)^{2-}$], and native elements (composed of single elements).
2. The most common carbonate minerals are calcite and dolomite.
3. Calcite—used in cement, Halite—source of common salt, Gypsum—used in plaster, Hematite—ore of iron, Fluorite—used in steelmaking, Ice—solid form of water, Galena—ore of lead, Pyrite—used to make sulfuric acid.

**3.9 Minerals: A Nonrenewable Resource**

1. Renewable resources—solar power, agricultural products such as corn and forest products. Nonrenewable resources—fuel sources such as oil and gas, metals such as aluminum and copper, and industrial raw materials such as limestone and gypsum.
2. A *mineral resource* would be any concentration of a useful mineral that can be utilized either currently or potentially in the future. By contrast, an *ore deposit* is a concentration that is currently extractable.
3. A mineral deposit that is currently not classified as an ore deposit could be upgraded if technology improves the efficiency of the extraction process or if the economics change for that mineral and the profitability of its extraction improves.

## CONCEPTS IN REVIEW

**3.2** A) 14 protons = silicon; B) 6 protons = carbon; C) 13 protons = aluminum; D) 17 protons = chlorine; E) 26 protons = iron.

**3.3** Diagram C shows ionic bonding. It shows a positively charged and a negatively charged atom, after one atom lost an electron to the other. These charged atoms are called ions, and this is a distinguishing characteristic of ionic bonding. In covalent bonds, valence electrons are shared between a pair of atoms.

**3.4** Quartz either has a hexagonal crystal form or is massive, whereas calcite is rhombohedral. Quartz (Mohs hardness 7) is also significantly harder than calcite (Mohs hardness 3). Quartz is a silicate mineral, and calcite is a carbonate mineral, so one can easily distinguish calcite by checking for an effervescent reaction with a drop of dilute hydrochloric acid. Calcite exhibits the special property of double refraction, whereas quartz does not. Finally, calcite exhibits cleavage in three directions not at 90º angles, while quartz does not exhibit cleavage, only conchoidal fracture.

**3.7** Nonferromagnesian silicates could be dark colored due to chemical impurities that cause the mineral to have a darker color. Also, crystal defects could cause optical effects that give the mineral a darker appearance.

## GIVE IT SOME THOUGHT

1. a. Gold nugget is a mineral.
   b. Seawater is not a mineral because it is a liquid, not a solid.
   c. Quartz is a mineral.
   d. Cubic zirconia is not a mineral because it is a manufactured synthetic, not naturally occurring.
   e. Obsidian is not a mineral because it does not have an ordered (crystalline) internal structure.
   f. Ruby is a mineral.
   g. Glacial ice is made of minerals.
   h. Amber is not a mineral because it is organic.

2. a. The name of the element is "uranium."
   b. The neutral atom has 92 electrons.
   c. The element has 146 neutrons.
3. The minerals with a nonmetallic luster are specimens A, B, and D while specimens C and E have a metallic luster.
4. A 5-gallon bucket of pure gold would weigh 800 pounds (20 x 40).
5. a. There are six flat surfaces on the mineral sample pictured.
   b. There are three different directions of cleavage in the mineral sample.
   c. The cleavage surfaces do not meet at 90-degree angles; otherwise, the broken sample would resemble a cube.
6. a. Hornblende
   b. Muscovite
   c. Quartz
   d. Olivine
   e. Plagioclase feldspar
   f. Clay
7. The mineral shown is illustrating the tenacity known as *elastic*. Also illustrated is the excellent cleavage exhibited by the mineral.
8. a. Stainless steel utensils—the minerals hematite and magnetite for the steel, chromite, and nickel ore
   b. Cat litter—bentonite clay and diatomaceous earth
   c. Tums brand antacid tablets—calcite (calcium carbonate)
   d. Lithium batteries—the minerals spodumene and graphite, and copper ore deposits
   e. Aluminum beverage cans—the aluminum ore "bauxite"
9. On a plant composed mostly of halide minerals, the most abundant elements would be chlorine, fluorine, and bromine along with sodium, calcium, and potassium. On a planet composed mostly of carbonate minerals, the most abundant elements would be oxygen and sulfur.
10. The silicate structure shown is the sheet structure. This structure is the result of three of the four oxygens being shared by adjacent tetrahedrons. The mica group of minerals is an important silicate group that exhibits this type of structure.