INSTRUCTOR RESOURCE MANUAL

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Foundations of Earth Science

Eighth Edition

Lutgens • Tarbuck • Tasa

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Contents

1. MATTER AND MINERALS

INTRODUCTION

Matter and Minerals presents the fundamental characteristics of earth materials. The chapter begins with minerals and how they are defined, then delves deeper to review the building blocks of minerals: atoms and atomic particles. From there, the main types of ionic bonding are presented. The final section in the chapter steps back to look at mineral properties, how minerals are identified, and the main mineral groups.

CHAPTER OUTLINE

1.1 MINERALS: BUILDING BLOCKS OF ROCKS

a. Defining a Mineral
b. What Is a Rock?

1.2 ATOMS: BUILDING BLOCKS OF MINERALS

a. Properties of Protons, Neutrons, and Electrons
b. Elements: Defined by Their Number of Protons

1.3 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

1.4 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: how easily minerals break or deform under stress
    i. Hardness:
    ii. Cleavage:
    iii. Fracture:
    iv. Tenacity:
d. Density and Specific Gravity
e. Other Properties of Minerals
    i. High iron content
    ii. Double refraction
    iii. Reaction to dilute hydrochloric acid

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1.5 MINERAL GROUPS

a. Silicate Minerals:
   i. Common light silicate minerals
   ii. Common dark silicate minerals
b. Important Nonsilicate Minerals

LEARNING OBJECTIVES/FOCUS ON CONCEPTS

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

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

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

1.3: **Distinguish** among ionic bonds, covalent bonds, and metallic bonds.

1.4: **List** and describe the properties used in mineral identification.

1.5: **List** the common silicate and nonsilicate minerals and describe what characterizes each group.

TEACHING STRATEGIES

- During lecture for this material, which is really heavy on terminology of mineral characteristics and groups, samples should be provided to the class in as many ways possible.
  - Actual mineral samples as compared with photos of ideal mineral samples, perhaps examples passed around the classroom as well as shown on a document camera where features can be pointed out.
  - Minerals should be shown on their own as crystals and in rock form. Often, students are confused about the difference between rocks and minerals; they need to be provided with examples first where minerals inside the rock can be seen clearly (e.g., a pegmatite), then with examples where only mineral faces can be identified but students can still see how the rock is composed of individual crystals (e.g., marble). Later, students should see these same rock samples when learning about igneous textures and the different rock characteristics—seeing them early should help them make connections later.
  - If possible, provide models of crystal structures and models of chemical bonding as well as example minerals that exhibit the same structure. It is difficult for students to “see” inside the mineral to identify crystal habit and the relation this holds to chemical bonding.
- Cleavage and fracture are difficult as well. The best way, perhaps, to show this is to do a demonstration where one uses a rock hammer to break a few more readily accessible mineral samples that exhibit cleavage and fracture. Seeing the same shape repeated in smaller form as a mineral cleaves helps a student understand where the plane of cleavage occurs, whereas when a mineral shatters like glass, it shows the student fracture.
- Luster, too, is often difficult, especially with darker-colored minerals and discerning metallic from vitreous. Examples of nonminerals that show each of the lusters should be used whenever possible as well—especially when demonstrating less intuitive categories, such as “dull-metallic.”

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TEACHER RESOURCES

The virtual museum of minerals and molecules: http://virtual-museum.soils.wisc.edu. This is a resource for instruction that includes 3D visualizations of minerals and molecules.

Index of mineral images: http://webmineral.com/specimens/index.php. This is a comprehensive image database of pretty much every single mineral.

Mineral crystal forms and paper models: http://webmineral.com/crystall.shtml. This site is organized by crystal forms and can be used at the introductory level for lower-division students as well as in mineralogy courses for upper-division students. Printable paper models of the various crystal forms are available for download that can be used for instruction and visualization of crystal structures.

ANSWERS TO QUESTIONS IN THE CHAPTER:

CONCEPT CHECKS

1.1

1. List five characteristics of a mineral.
   - **a.** *naturally occurring*
   - **b.** *inorganic*
   - **c.** *solid substance*
   - **d.** *ordered crystalline structure*
   - **e.** *definite chemical composition*
2. Based on the definition of a mineral, which of the following—gold, liquid water, synthetic diamonds, ice, and wood—are not classified as minerals?

   Wood is not a mineral because it is organic. Synthetic diamonds are not naturally occurring, so they too would not be considered minerals. Water is liquid, so it is not considered a mineral; however, its frozen counterpart, ice, would be. Thus, only gold and ice are considered minerals from this list based on the definition provided in question 1.
3. Define the term *rock*. How do rocks differ from minerals?

   A rock is a solid aggregate of minerals or of mineral-like matter. Rocks may have a single mineral composition (such as marble—formed only of the mineral calcite) or a multimineral composition (such as granite—formed mainly of quartz, orthoclase, plagioclase, and biotite), or be made of nonminerals (such as coal—formed from heated and compressed plant matter, or pumice, which is formed from volcanic glass). Minerals, by contrast, have a very specific definition.

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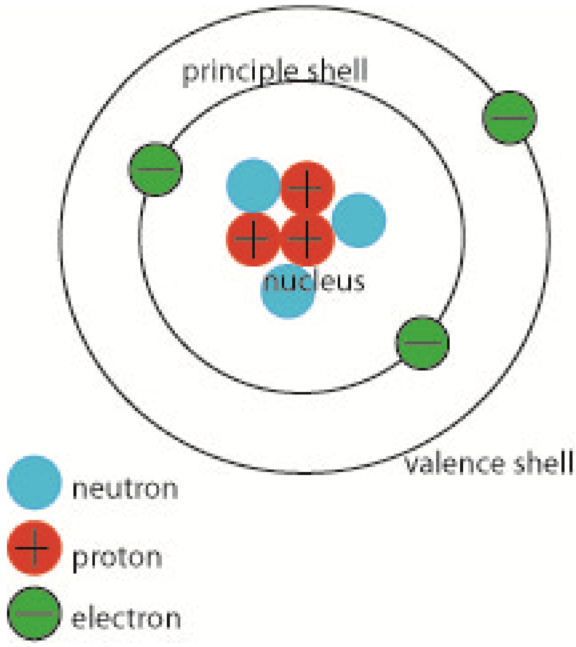
1.2

1. Make a simple sketch of an atom and label its three main particles. Explain how these particles differ from one another.

   Lithium, for example.



   Atoms are made of protons, neutrons, and electrons. Both protons and neutrons have atomic mass and reside in the nucleus of atoms. Protons are positively charged, and neutrons have no charge. Electrons reside outside the nucleus, orbiting in "shells." Electrons have negligible mass and a negative charge.

2. What is the significance of valence electrons?

   Valence electrons are located in the outermost shell of an atom and are the electrons that interact with other atoms' electrons to form chemical bonds.

1.3

1. What is the difference between an atom and an ion?

   An ion is an atom that has become positively charged or negatively charged by losing one or more valence electrons or gaining one or more valence electrons, respectively.

2. How does an atom become a positive ion? A negative ion?

   A positive ion has lost one or more electrons, leaving the positively charged protons in the nucleus without a balancing negative charge on the particle, resulting in a positively charged ion. A negative ion has gained one or more electrons, adding more negative charge to the orbital shells, resulting in a negatively charged ion.

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3. Briefly distinguish between ionic and covalent bonding and discuss the role that electrons play in both.

   Ionic bonding involves a transfer of electrons from the valence shell of one atom to the valence shell of another. The result of this electron transfer is two oppositely charged ions that are strongly attracted to each other and join to form an ionic compound. Covalent bonding involves the sharing of pairs of valence shell electrons between two atoms.

1.4

1. Define luster.

   Luster is the quality of the light reflected from the surface of a mineral.

2. Why is color not always a useful property in mineral identification? Give an example of a mineral that supports your answer.

   Color is frequently not a diagnostic property for mineral identification because tiny impurities in the mineral's chemical composition can influence or dramatically change the mineral's color. Fluorite, for example, can be yellow, clear, blue, or purple.

3. What differentiates cleavage from fracture?

   Cleavage is a natural break along a plane of weak bonding within a mineral's crystal structure. Cleavage will result in smaller pieces of the mineral, all with the same geometry as the original crystal. Fracture is a break that results from a mineral having relatively equal strength bonds in all directions that make up its crystal form. Consequently, all the products of fracture are different and irregular or conchoidal shapes.

4. What is meant by a mineral's tenacity? List three terms that describe tenacity.

   A mineral's "tenacity" is its "toughness." This is its resistance to breaking. Tenacity can be described as "brittle" if a mineral shatters, "malleable" if a mineral can be hammered into different shapes, or "elastic" if it is flexible.

5. Describe a simple chemical test that is useful in identifying the mineral calcite.

   Calcite is a carbonate mineral, which is a mineral group most readily identified by the effervescent reaction to a drop of dilute hydrochloric acid.

1.5

1. List the eight most common elements in Earth's crust.

   Oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium.

2. Explain the difference between the terms *silicon* and *silicate*.

   Silicon is the single element Si, atomic number 14. Silicates are the mineral group that is based on the silicon–oxygen tetrahedron (mineral building block made of one silicon atom surrounded by four oxygen atoms), and all silicates contain this compound.

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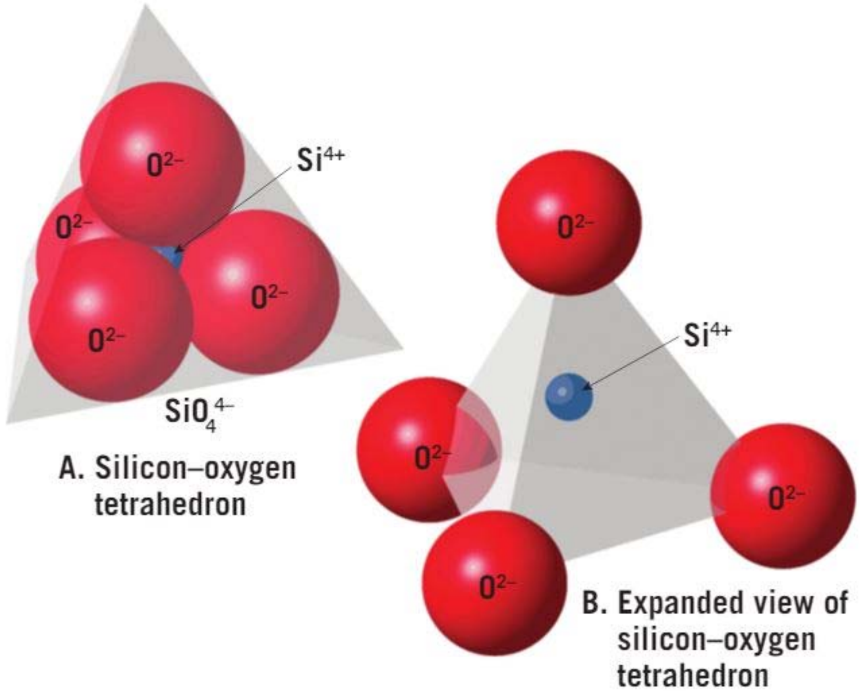
3. Sketch the silicon–oxygen tetrahedron and label its parts.



4. What is the most abundant mineral in Earth's crust?

Feldspars.

5. List six common nonsilicate mineral groups and the key ion(s) or element(s) in each group.

Oxides (O), carbonates (CO_3), sulfates (SO_4), halides (contain a halogen, such as Cl or Fl), sulfides (contain S and a metal), and native elements (pure single element compounds, such as gold, silver, and copper).

6. What is the most common carbonate mineral?

Calcite ($CaCO_3$)

7. List eight common nonsilicate minerals and their economic uses.

galena (sulfide; lead ore)

gypsum (sulfate; drywall)

halite (halide; table salt)

graphite (native element carbon; pencils, lubricant)

hematite (oxide; iron ore)

chalcopyrite (sulfide; copper ore)

corundum (oxide; abrasive)

gold (native element; jewelry, electronics, dentistry)

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Concepts in Review

1.2: Use the periodic table (see Figure 1.5) to identify these geologically important elements by their number of protons: (A) 14, (B) 6, (C) 13, (D) 17, and (E) 26.

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

1.3: Which of the accompanying diagrams (A, B, or C) best illustrates ionic bonding? What are the distinguishing characteristics of ionic versus covalent bonding?

The third situation in the diagram 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. Covalent bonds do not contain ions, as valence electrons are shared between a pair of atoms.

1.4: Research the minerals *quartz* and *calcite*. List five physical characteristics that may be used to distinguish one from the other.

Both quartz and calcite are minerals that are typically vitreous and transparent and can occur in a variety of colors. However, 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.

Give It Some Thought

1. Using the geologic definition of *mineral* as your guide, determine which of the items in this list are minerals and which are not. If something in this list is not a mineral, explain.

- **a.** Gold nugget—*mineral*
- **b.** Seawater—*not a mineral; it is not solid*
- **c.** Quartz—*mineral*
- **d.** Cubic zirconia—*not a mineral; not naturally occurring*
- **e.** Obsidian—*not a mineral; not composed of a definite chemical composition or orderly internal structure (a rock of volcanic glass)*
- **f.** Ruby—*mineral*
- **g.** Glacial ice—*mineral*
- **h.** Amber—*not a mineral; organic substance*

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2. Assume that the number of protons in a neutral atom is 92 and its atomic mass is 238.03. (*Hint*: Refer to the periodic table in Figure 1.5 to answer this question.)

a. What is the name of the element?
Uranium—mass number tells you the place on the periodic table, this is the atomic number.

b. How many electrons does it have?
92—if the atom is neutral, there must be the same number of protons as there are neutrons.

c. Given its atomic mass, how many neutrons must it have?
146—the total mass will be the sum of the protons and neutrons. 238 (mass) − 92 (protons) = 146 (neutrons)

3. Referring to the accompanying photos of five minerals, determine which of these specimens exhibit a metallic luster and which have a nonmetallic luster.

Specimens A, B, and D all have a nonmetallic (vitreous) luster. Specimens C and E have a metallic luster.

4. Gold has a specific gravity of almost 20. A 5-gallon bucket of water weighs 40 pounds. How much would a 5-gallon bucket of gold weigh?

The specific gravity of water (at 4ºC) is 1. If 5 gallons of water weighs 40 pounds, then 5 gallons of gold (specific gravity = 20) would be 20 times more. This would weigh 800 pounds.

5. Examine the accompanying photo of a mineral that has several smooth, flat surfaces that resulted when the specimen was broken.

a. How many flat surfaces are present on this specimen? *Six (6)*

b. How many different directions of cleavage does this specimen have? *Three (3)*

c. Do the cleavage directions meet at 90-degree angles? *No.*

6. Each of the following statements describes a silicate mineral or mineral group. In each case, provide the appropriate name.

a. The most common member of the amphibole group: *hornblende*

b. The most common light-colored member of the mica family: *muscovite*

c. The only common silicate mineral made entirely of silicon and oxygen: *quartz*

d. A silicate mineral with a name that is based on its color: *olivine*

e. A silicate mineral that is characterized by striations: *plagioclase, orthoclase (feldspars)*

f. A silicate mineral that originates as a product of chemical weathering: *clay (kaolinite)*

7. What mineral property is illustrated in the accompanying photo?

Elasticity and perfect single direction of cleavage.

8. Do an Internet search to determine what minerals are used to manufacture the following products.

a. Stainless steel utensils—*made from iron and chromium plus nickel. Iron is derived from hematite, goethite, and limonite mostly. Chromium is derived mainly from chromite, and nickel usually comes in sulfide form (pentlandite mainly).*

b. Cat litter—*bentonite clay, diatomite*

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- **c.** Tums brand antacid tablets—*calcium carbonate (calcite) +/- magnesite*
- **d.** Lithium batteries—*spodumene and petalite in pegmatitic granites or lepidolite*
- **e.** Aluminum beverage cans—*bauxite*

9. Most states have designated a state mineral, rock, or gemstone to promote interest in the state's natural resources. Describe your state mineral, rock, or gemstone and explain why it was selected. If your state does not have a state mineral, rock, or gemstone, describe one from a state adjacent to yours.

California's state gem is benitoite, which is a rare blue barium mineral that fluoresces under black light. It is named for the county it was found in: San Benito County. California's state mineral is gold, chosen because of the California gold rush and the importance of that time in California's history. Gold is a native element. California's state rock is serpentinite, which is found throughout California due to the tectonic history of the state. It is a metamorphic rock, metamorphosed from oceanic crust.

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