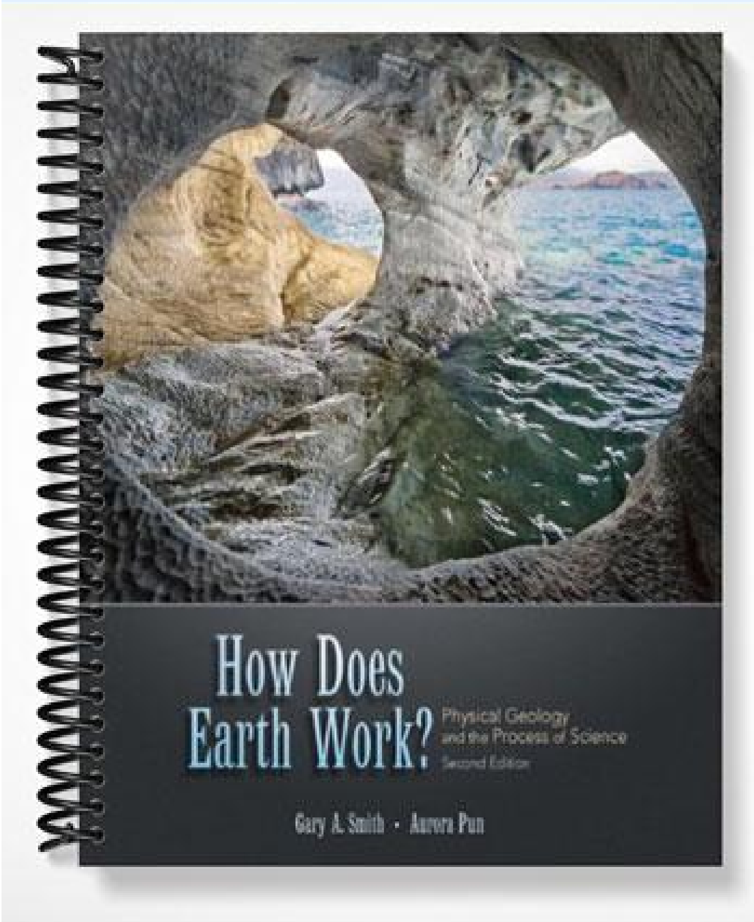
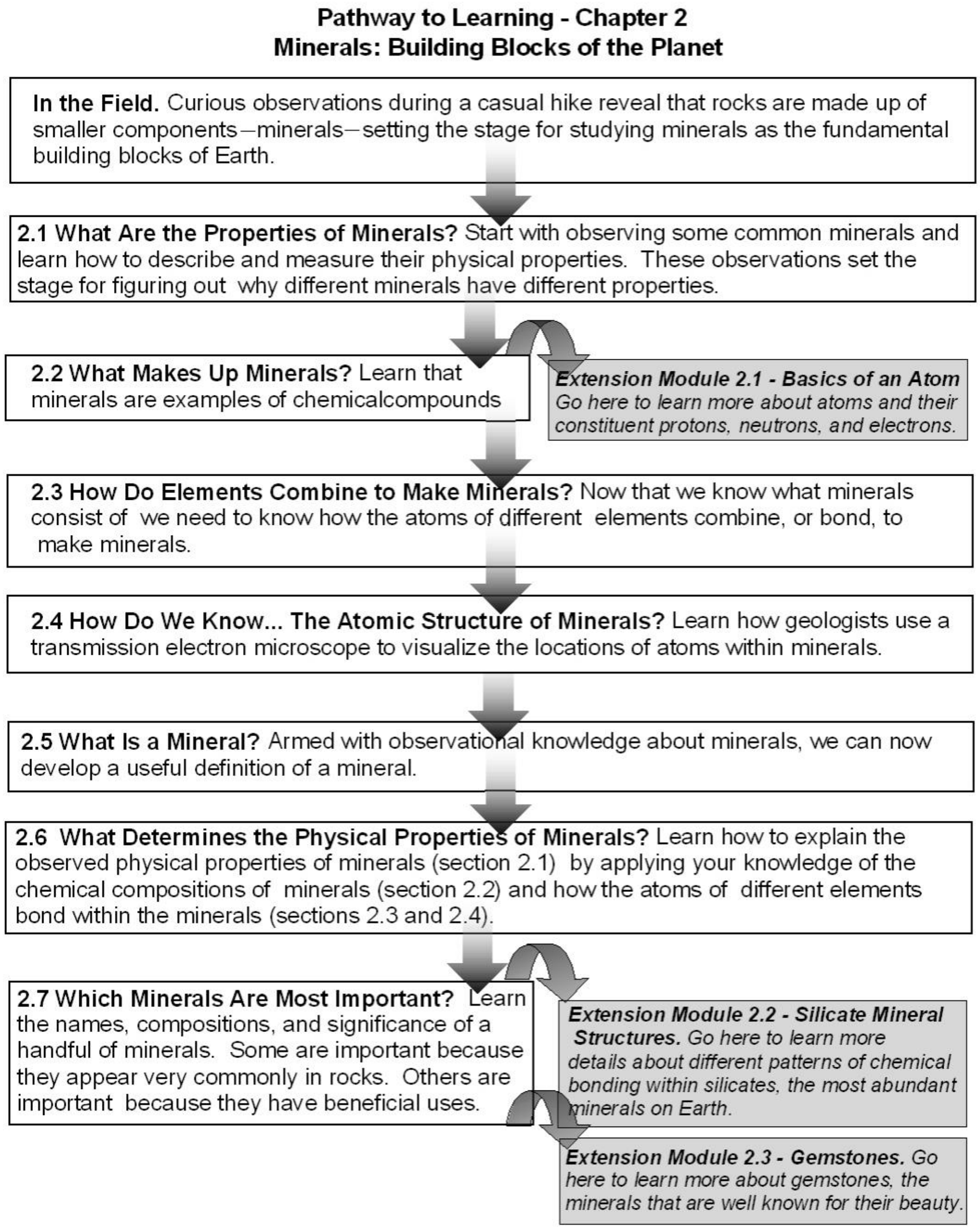
TEST BANK


How Does
Earth Work?
Physical Geology
and the Process of Science
Second Edition
Gary A. Smith • Aurora Pun

CHAPTER 2: MINERALS: THE BUILDING BLOCKS OF THE PLANET

Expanded Pathway to Learning • Authors' Intent • Learning Outcomes • Animations for You and Your Students • Active Learning Ideas • End-of-Chapter Questions and Answers



Authors' Intent

The study of minerals is a fundamental aspect of our understanding of rocks; therefore we follow the tradition of placing mineralogy ahead of the chapters devoted to the major rock groups. Most physical geology textbooks cover the mineralogy chapter by including the basic facts of what minerals are, how elements bond to form minerals and the identification of minerals. *How Does Earth Work?* takes a different approach. We use observations of a few

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minerals to deduce attributes common for all minerals and use these observation to build a definition of "mineral." Along the way, we offer explanations for why minerals exhibit different physical properties and simultaneously introduce important concepts about the composition and bonding characteristics of minerals. We emphasize the most important minerals, which we view as the principal rock-forming minerals (mostly silicates) and others with important uses.

The "How Do We Know?" sections endeavor to illustrate some aspect of scientific method as it is applied in geology. In this chapter, we illustrate the use of modern technology to understand fundamental geologic phenomena. The importance of composition and structure in minerals can seem abstract to students, especially since they cannot see the atoms that comprise minerals. The "How Do We Know?" section explains how geologists can "see" atoms using the transmission electron microscope and, therefore, how we can make interpretations about how minerals form. From this information, we can infer how the composition and the arrangement of atoms explain the physical properties of minerals.

As with the text as a whole, we assume that students have had a high school chemistry or physical science class and can apply knowledge learned in such a class. But as a refresher, we devote some attention to the basic components of the atom within the text chapter. Appreciating that some students may find these concepts difficult to remember and may need a more detailed review, we have prepared **Extension Module 2.1** on the companion website that covers these fundamentals. The students can use this module as a remedial brush up to facilitate understanding of the text.

The silicate mineral structures are included in some physical geology texts and excluded from others. In our experience, the geometry of shared tetrahedra and the Si:O ratios are intimidating to many students and add very little to most instructors' goals for learning about minerals in a survey course. For the geoscience major, this topic will reappear in their mineralogy course where a firm grounding in chemistry is expected. For the interested student or for the instructor who feels that teaching the silicate structures is essential, we provide **Extension Module 2.2** on the subject.

Many physical geology books provide a survey of a handful of minerals common in the Earth's crust. We find these encyclopedic descriptions of minerals difficult to read and therefore, have incorporated most of this information into a table. Additional information about gemstones is provided within **Extension Module 2.3**, which provides a connection between minerals as geologists know them best to minerals as most student consumers know them best.

This is the first chapter that contains student-media extension modules. The modules for this chapter, as for the book as a whole, were not intended as supplements but as optional text content that the instructor can choose to assign or not, and which curious students may choose to pursue on their own. The written text is constructed independent of the extension modules so that a student does not need to go to the modules in order to understand and follow content in the written text.

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Learning Outcomes

Use this information as a guide to decide what you want your students to focus on when making assignments in this chapter.

Stated student learning outcome (page 20)	Chapter sections that help build mastery of the outcome	End-of-the-chapter questions that assess the outcome
Explain that each mineral has a definitive chemical composition and internal atomic structure.	2.1 (background knowledge) 2.2 (background knowledge) 2.3 2.4 2.5 Extension Module 2.2	*Confirm Your Knowledge*: 1, 2, 6, 7, 14 *Confirm Your Understanding*: 2, 4
Relate physical properties of minerals to their chemical composition and structure.	2.1 (background knowledge) 2.2 (background knowledge) 2.3 2.4 2.6	*Confirm Your Knowledge*: 2, 3,4,5,6, 9. 10,11 *Confirm Your Understanding*: 4, 5, 6
Describe examples of minerals that are important to your life and the products you use.	Introduction page In the Field 2.1 2.7 Extension Module 2.3	*Confirm Your Knowledge*: 15 *Confirm Your Understanding*: 3
Refer to the names, compositions, and properties of an important handful of the more than 4000 known minerals.	2.7	*Confirm Your Knowledge*: 13

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This chapter permits opportunities to develop course-scale outcomes mastery:

Course-level outcome	Relevant examples in the chapter	Assessment possibilities
Understanding how geoscientists collect data	There are several examples in this chapter. Observations of different physical characteristics of minerals are used to infer differences in composition and internal arrangement of atoms (section 2.1). Section 2.4 illustrates how geoscientists collect TEM data to infer the internal arrangement of atoms in minerals. Characteristics and properties of minerals are also used to determine economically valuable resources (section 2.7).	Consider asking clicker questions with photos of minerals with various colors to infer variations in composition. Or, ask students to compare and contrast diamond and graphite (Fig. 2.23). Questions to assign/discuss: *Confirm Your Knowledge* 2, 3, 4, 7, 8, 9, 10
Interpreting graphical displays of quantitative data	Of particular relevance to learning, there is a graph of Mohs hardness scale compared to absolute hardness which is a log scale plot (Fig. 2.4). There is also a graph of sizes of ions (Fig 2.22) which shows variation in charges from center of the graph and simultaneously shows pictorial sizes of ions. Fig. 2.24 shows a three-dimensional graph with three axes. Each of these examples requires students to think more deeply than for simple binary plots.	Consider clicker questions that address reading the log scale graph (Fig. 2.4) or asking how charges of ions may vary with size of the ions (Fig. 2.22). Questions to assign/discuss: *Confirm Your Knowledge* 4, 12, 13. See *Active Learning Ideas* for this chapter.
Using evidence to support a scientific conclusion.	Observations of hardness tests and cleavage show a relationship to mineral composition and internal arrangement of atoms (sections 2.1, 2.3, and 2.6). Fig. 2.24 can be used to infer why silicates are the dominant rock-forming minerals. The *How Do We Know…* section models all aspects of scientific problem solving, from posing the question, to experimental design, to interpretation of results.	Ask students to compare and contrast two different minerals using observations or descriptions of their physical properties. Clicker questions can be used to ask for interpretations of various physical properties or other characteristics (i.e., what makes one mineral harder than the other, what can make the same mineral different colors, is there a limit to the number of minerals possible). Ask students to explicitly explain the role of evidence in supporting the interpretations in the *How Do We Know…* section. Questions to assign/discuss: *Confirm Your Knowledge* 3, 7, 9, 12; *Confirm Your Understanding* 6.

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		See *Active Learning Ideas* for this chapter.
Applying conceptual understanding to relevant or interesting problems	The chapter illustrates that we can take advantage of the physical properties of minerals for resource purposes.	Ask students the types of minerals they use on a daily basis or some of the uses of specific minerals, such as talc, iron, aluminum, graphite, or why we use metals for pots, etc. Extension Module 2.3 can be assigned to show how physical properties are used to determine the "social value" of gemstones. Questions to assign/discuss: *Confirm Your Knowledge* 15; *Confirm Your Understanding* 2, 3. See *Active Learning Ideas* for this chapter.
Synthesizing information to develop new understanding	Understanding the link between composition and internal arrangement of atoms to determine the physical properties of minerals. Understanding the limited number of ways elements can be combined and linking this with the two dominant elements in Earth's crust to infer why silicates are the major rock-forming minerals on Earth.	Questions to assign/discuss: *Confirm Your Knowledge* 14; *Confirm Your Understanding* 2, 4, 5, 6. See *Active Learning Ideas* for this chapter.

Relating content and outcomes in this chapter to the rest of *How Does Earth Work?*

- Common minerals described in Table 2.2 reappear throughout the rest of the textbook. Students should be encouraged to use Table 2.2 as a reference resource throughout the course.
- The major rock-forming minerals (Section 2.7) provide a basis for describing the composition of the three major rock groups discussed in Chapters 4–6.

Animations for You and Your Students

There are no animations in the Geoscience Animation Library that link to the content of this chapter.

Active Learning Ideas

Clicker Questions - ConcepTests

Do you use a classroom response system in your class? There are pre-prepared PowerPoint slides with clicker questions available for you to use at the instructor resources web page.

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Additional questions are available on the ConcepTest page at the Science Education Resource Center (SERC): http://serc.carleton.edu/introgeo/interactive/ctestexm.html. Useful search phrases include: "ConcepTest mineral" (9 questions), "ConcepTest atom" (3 questions).

For more information about teaching and learning with classroom response systems, see Chapter 3 in Part I of this instructors' resource guide and SERC. (http://serc.carleton.edu/introgeo/interactive/conctest.html)

Think/Write-Pair-Share Prompts

For more information about the implementation and purpose of think/write-pair-share questions, refer to Chapter 3 in Part I of this instructors' resource guide.

Compare and contrast the physical properties of calcite and quartz.

What can cause color variations within the same type of mineral?

How can you use the physical properties of minerals to identify an unknown mineral you encountered while out hiking?

What is the difference between a crystal face and a cleavage plane?

How are the physical properties of minerals related to composition and the internal arrangement of atoms?

How does chemical bonding influence mineral solubility?

What happens at the atomic scale when halite dissolves in a glass of water? What would happen if you place a piece of calcite into a glass of water? Does it dissolve like halite?

How do geoscientists figure out the internal arrangement of atoms in a mineral?

Use graphite and diamond as examples to explain how the internal arrangement of atoms in minerals determines their physical properties.

Why are silicates the most common group of rock-forming minerals?

Name some minerals you use in your everyday life.

What are some of the uses of iron ore, zinc, titanium oxide, and copper?

In-Class Exercises (Lecture Tutorials)

For more information about the implementation and purpose of in-class exercises, refer to Chapter 3 in Part I of this instructors' resource guide.

Two examples are provided of exercises that author Aurora Pun has her physical geology students complete in pairs during class time. Answer keys follow each exercise.

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In-Class Exercise: Mineral Observations

In the plastic baggie are 3 minerals. Briefly describe each of the three minerals and list things that are different or similar about them.

Description of Min 1	Description of Min 2	Description of Min 3

List differences among the three minerals

1.

2.

3.

List similarities among the three minerals

1.

2.

3.

Now that your team has spent a few minutes observing these minerals, please explain why these minerals look different or look similar.

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KEY: In-Class Exercise: Mineral Observations

Notes to Instructor: Various sets of minerals could be used, or even just two minerals. I usually provide one set of minerals per 2–3 students. I give them about 10 minutes to work.

Description of Min 1	Description of Min 2	Description of Min 3
Quartz – 6 sided, maybe doubly terminated (6 sided on each end), clear, glassy looking, pointy	***Calcite – 6 sides, squashed cube, rhomb, clear, glassy looking***	***Halite – squares, cubes, clear, glassy looking***

List differences among the three minerals

There are various possible answers

1. ***different shapes***
2. ***may be of different colors***
3. ***different opaqueness, clarity***

List similarities among the three minerals

There are various possible answers

1. ***all six-sided***
2. ***all clear, all glassy looking (luster)***
3. ***all have crystal faces***

Now that your team has spent a few minutes observing these minerals, please explain why these minerals look different or look similar.

The differences or similarities are a reflection of their composition and internal structure. It's what atoms are involved and how they are packed together. This determines how they form their shape and cleavage, how hard they are, if they are clear, etc.

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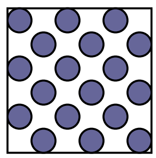
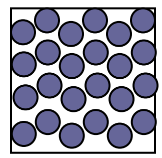
In-Class Exercise: What is density?

Density is a measurement of how much stuff (the mass) is contained in a given space (the volume).

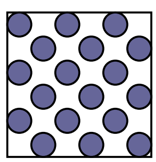
1. Assume all of the illustrated gray balls have the same mass. Which one of the boxes below has the higher density? Explain your answer using the words mass and volume.

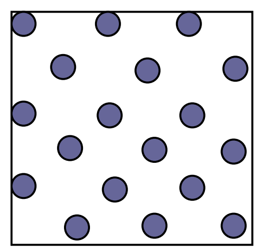




a) b)

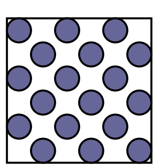
2. Assume that all of the gray balls have the same mass. Which one of the boxes below has the higher density? Explain your answer.





a) b)

3. Assume that all of the gray balls have the same mass. Using the diagram below: (a) how could you increase the density without changing the size of the box? (b) How would you increase the density without changing the mass?



4. A block of material is 1 meter (m) tall, 2 m wide, and 5 m long. The block has a mass of 300 kg. What is the density of the box in kg/m^3?

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KEY: In-Class Exercise: What is density?

1. B has the higher density because it has greater mass in the same amount of volume. There are more spheres in option B.

2. Both options A and B have the same number of spheres, and therefore the same amount of mass. B has more volume, so its density is lower than A. So, A has a higher density.

3. (a) You can change the density by adding more mass, in other words, adding more spheres. (b) to increase density without adding more mass, you would have to decrease the volume, by making the box smaller.

4. 1m x 2m x 5m = $10m^3$ (volume); mass = 300kg Density is mass/volume = $300kg/10m^3 = 30kg/m^3$

To assess learning from this exercise, consider clicker questions like these:

Mineral specimen 1 has a volume of 15 cm^3 and a mass of 45 g. Mineral specimen 2 has a volume of 30 cm^3 and a mass of 60 g. Which mineral has a higher density?

A. Mineral specimen 1

B. Mineral specimen 2

Two mineral specimens have an identical mass. Mineral specimen 1 has a density of 2.5 g/cm^3. Mineral specimen 2 has a density of 3.0 g/cm^3. Which specimen is larger (in other words, has the greater volume)?

A. Mineral specimen 1

B. Mineral specimen 2

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Online Teaching and Learning Resources

Resources at the SERC Website (Summary excerpts from SERC)

Mining, We Depend on It: An extended think-pair-share based on an advertisement from a newspaper that proclaimed "Life in a 125 ton mineral" deposit, with a picture of an American Dream Home, and a long list of raw materials and natural resources that went into the construction of the house. Final caption: "Mining. We depend on it." This activity shows students right away that the course is built around in-class activities (i.e., active learning, small group work, participation) and it also highlights connections to many topics that can be covered throughout the term.
http://serc.carleton.edu/introgeo/firstday/activities/21689.html

Is it a Mineral? Six or seven objects are given to small groups of three to five students. All groups have the same six or seven objects. All are asked to work with their group to determine which are minerals and which are not and to determine why. After a few minutes, call on individuals in the class to choose an object and tell you whether or not it is a mineral and why.
http://serc.carleton.edu/introgeo/firstday/activities/21708.html

Silicate Structures: Chalkboard demonstration: This assignment is designed to introduce the silicate structures, and their significance to mineral properties, to undergraduate non-science majors in an introductory physical geology course. Magnetic representations of Si tetrahedra and cations are manipulated on a chalkboard as students explore the relationships between structure, bond strength, cleavage, Si:O ratio, and mineral formulae, etc. This activity is a tactile, collaborative, classroom demonstration that, when used in conjunction with a standard lecture introduction to the silicates, provides a reinforced lesson for students with varied learning styles and limited knowledge and/or comfort in the realm of science.
http://serc.carleton.edu/NAGTWorkshops/intro/activities/24296.html

Smithsonian Education Lessons on Minerals and Gems

The Smithsonian Natural History Museum has some simple lesson plans that involve identifying minerals, making crystals and even has a mineral scavenger hunt. These exercises are designed for K–12 classes, but can easily be adapted.
http://www.smithsonianeducation.org/educators/lesson_plans/minerals/minerals_crystals.html

End-of-Chapter Questions and Answers (p. 40)

Confirm Your Knowledge

1. "Element," "mineral," and "rock" are important terms used in this chapter. Define each term using your own words, and then explain how the terms relate to one another.

Elements are the basic chemical building blocks of matter. An element is a material that cannot be broken down or changed into another substance suing chemical means. Minerals are chemical compounds consisting of combinations of atoms of one or more elements. Rocks consist of one or more than one, and usually several, different minerals.

2. Calcite and quartz are minerals. What properties do they have in common? How do they

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differ?

Common
Transparent
Six-sided crystals
Shiny, glass-like luster
Density

Different
Different shapes of their crystal faces
Different hardness
Calcite has three directions of cleavage, quartz has none
They have different chemical formulas

3. List and define the physical properties used to identify minerals.

Luster describes how mineral surfaces reflect light. Crystal faces are flat, smooth surfaces on mineral exteriors with regular geometric forms. Density is the measure of the mass of a material divided by its volume. Hardness is the resistance to scratching on a smooth surface. Cleavage describes planes along which a mineral breaks and the shape of the resulting fragments. Streak is the color of the residue remaining from scratching a mineral on a non-glazed porcelain plate. Color results from the interaction of light with the mineral.

4. Why is color not always a useful property in identifying a mineral?

Color is not a useful property in identifying a mineral because a mineral's color can vary significantly with very small changes in composition and because many different minerals can be the same color.

5. Use the absolute hardness scale (Figure 2.4) to determine how many times harder fluorite is than gypsum.

According to Figure 2.4, fluorite is 20 times harder than talc and gypsum is 2 times harder than talc, so fluorite is 10 times harder than gypsum.

6. List and describe the four types of bonds exhibited in minerals. Give an example of a mineral that exhibits each type of bond.

Ionic bonds occur when oppositely charged ions are attracted to one another. Example: halite, calcite, quartz

Covalent bonds occur when atoms share electrons. Example: calcite, quartz, diamond, graphite

Metallic bonds occur when electrons roam freely around a number of atoms. Example: gold, copper

7. How does a geologist "see" atoms?

TEM - Transmission electron microscope. Magnets focus streams of electrons; detector determines which electrons passed through the materials, and which encountered obstacles, revealing the internal arrangement of atoms and thus structure.

8. Does a TEM image detect all the elements in a mineral sample? Why or why not?

Most of the size of an atom consists of the cloud of electrons that orbit the nucleus. If there are many electrons in a small area around the nucleus, then there is a good chance that electrons fired in the TEM will collide with an orbiting electron and bounce off

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elsewhere in the microscope rather than continuing through to the detector. If, however, the electrons are widely spaced around a nucleus, then the fired electrons may pass through the atom without hitting any obstacles. This means that the shadows in the TEM image may not represent all of the types of atoms in a mineral, but rather only the atoms with closely clustered electrons.

9. *Why do some minerals exist in more than one color?*

Element substitutions. Examples: purple quartz contains iron substituting for silicon, pink quartz contains titanium substituting for silicon, dark blue, green, or brown calcite contain iron substituting for calcium, pale purple to deep red calcite contains manganese substituting for calcium.

Impurities without element substitution. Examples: milky quartz has water droplet impurities.

Radiation damage: black smoky quartz.

10. *What factors determine the density of a mineral?*

Density is the measure of the mass of a material divided by its volume, so the factors include mass of the material, the volume, the size of the atoms which influences the mass.

11. *How does cleavage differ from fracture? How does cleavage relate to mineral structure?*

Cleavage planes are the flat smooth surfaces along which some minerals break and the shape of the resulting fragments. Fracture is non-uniform breakage of a mineral. Cleavage planes form where bonds are weakest.

12. *What is the implication for the composition of Earth's interior if iron represents almost 35 percent of the entire Earth's composition, but less than 6 percent of Earth's crust?*

The rest of Earth besides the crust must be very rich in iron.

13. *Why are silicates the dominant rock-forming minerals?*

Silicates are the dominant rock-forming minerals because silicon and oxygen, the components of silicates, are the two dominant elements in Earth's crust.

14. *Silicates are the most common mineral group and differences between some silicates are due to only slight variations in their compositions. Explain the conditions necessary for elements to substitute to occur for Si and Mg.*

Substitution of one element must be of comparable size to fit into the same site in crystal structure.

Al^{3+} swaps for Si^{4+} in silicate tetrahedron.

Charge differences must be accommodated.

Add other cations (positive charges); no longer quartz.

Mg^{2+} and Fe^{2+} are similar size and charge and swap readily in minerals such as olivine.

15. *Give two uses for each of the following metals. Also list the minerals that are common ores for each metal.*

Iron Lead Zinc Aluminum Copper

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Iron: making steel, red pigment, magnets

Lead: pipes, storage vessels, ceramic glazes, glassware, car batteries, munitions, gasoline

Zinc: galvanizing, white pigment, ointments, lotions, pennies

Aluminum: lightweight metal, abrasive, gem stones

Copper: wire, bronze, zinc, weapons, tools, jewelry, pipes, utensils

Confirm Your Understanding

1. Write an answer for each question in the section headings.

Open-ended questions. Authors suggest that the instructor develop a rubric that matches outcomes and expectations for the students. In particular, expect students to provide examples and evidence to support their answers, and expect more than a repetition of the *Putting it Together* text provided at the end of each section.

2. For a substance to be a mineral, it must be a naturally occurring inorganic solid with a definite chemical composition and an ordered atomic arrangement. For each of the following substances, determine whether or not it is a mineral. If it is not a mineral, list all of the mineral properties that do not apply to it.

a. amber: NO organic solid; no definite chemical composition; no ordered atomic arrangement.

b. beer: NO not naturally occurring; organic solid; no definite chemical composition; no ordered atomic arrangement.

c. calcite: YES

d. diamond: YES

e. emerald: YES

f. plagioclase feldspar: YES

g. glacial ice: YES

h. halite: YES

i. ice cubes from an ice machine: YES (because ice is a naturally occurring mineral)

j. rock candy: NO not naturally occurring; organic solid; no definite chemical composition; no ordered atomic arrangement.

k. kryptonite: NO not naturally occurring; organic solid; no definite chemical composition; no ordered atomic arrangement.

l. cubic zirconia: NO not naturally occurring; organic solid; no definite chemical composition; no ordered atomic arrangement.

m. mineral oil: NO not naturally occurring; organic solid; no definite chemical composition; no ordered atomic arrangement.

n. muscovite: YES

o. obsidian: NO no ordered atomic arrangement.

3. Minerals have a wide variety of applications. Select five of the following substances and identify what minerals they contain.

Baby powder: talc
Antacid: calcite
Toothpaste: calcite

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Toothpaste with sparkles: mica
Epsom salt: epsomite
Red lipstick: talc and hematite
Red blush: talc and hematite
Table salt: halite
Kitty litter: zeolites

4. Diamond and graphite have the same chemical composition, but are different minerals, because their atoms are arranged differently. Research and write a paragraph comparing another pair of minerals that share the same chemical composition.

Possible mineral choices:

quartz; stishovite; coesite; cristobalite; tridymite
kyanite; andalusite; sillimanite
rutile; anatase; brookite
diamond; graphite
microcline; orthoclase; sanidine
pyrite; marcasite

5. Determine whether your state has a state gemstone or mineral. If it does, research that gemstone or state mineral and list its chemical formula, name two of its physical properties, and explain why it was chosen as the state gemstone or mineral.

About.com: Geology is a good source of a list and illustrations of state gemstones; http://geology.about.com/od/regional_geology/ig/stategems/

6. Consider how easily halite (NaCl) dissolves in water. Why does quartz not dissolve readily in water?

Halite dissolves relatively easily because it forms from ionic bonds of elements that only have a charge value of one. Weak attraction results from lopsided distribution of electrons; positive ends of the water molecule (H^+) are attracted to and dislodge the anions (Cl^-) and the negative ends of the water molecule (O^-) are attracted to and dislodge the cations (Na^+). Water keeps the ions separated. In contrast, bonds in quartz are mostly covalent.

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