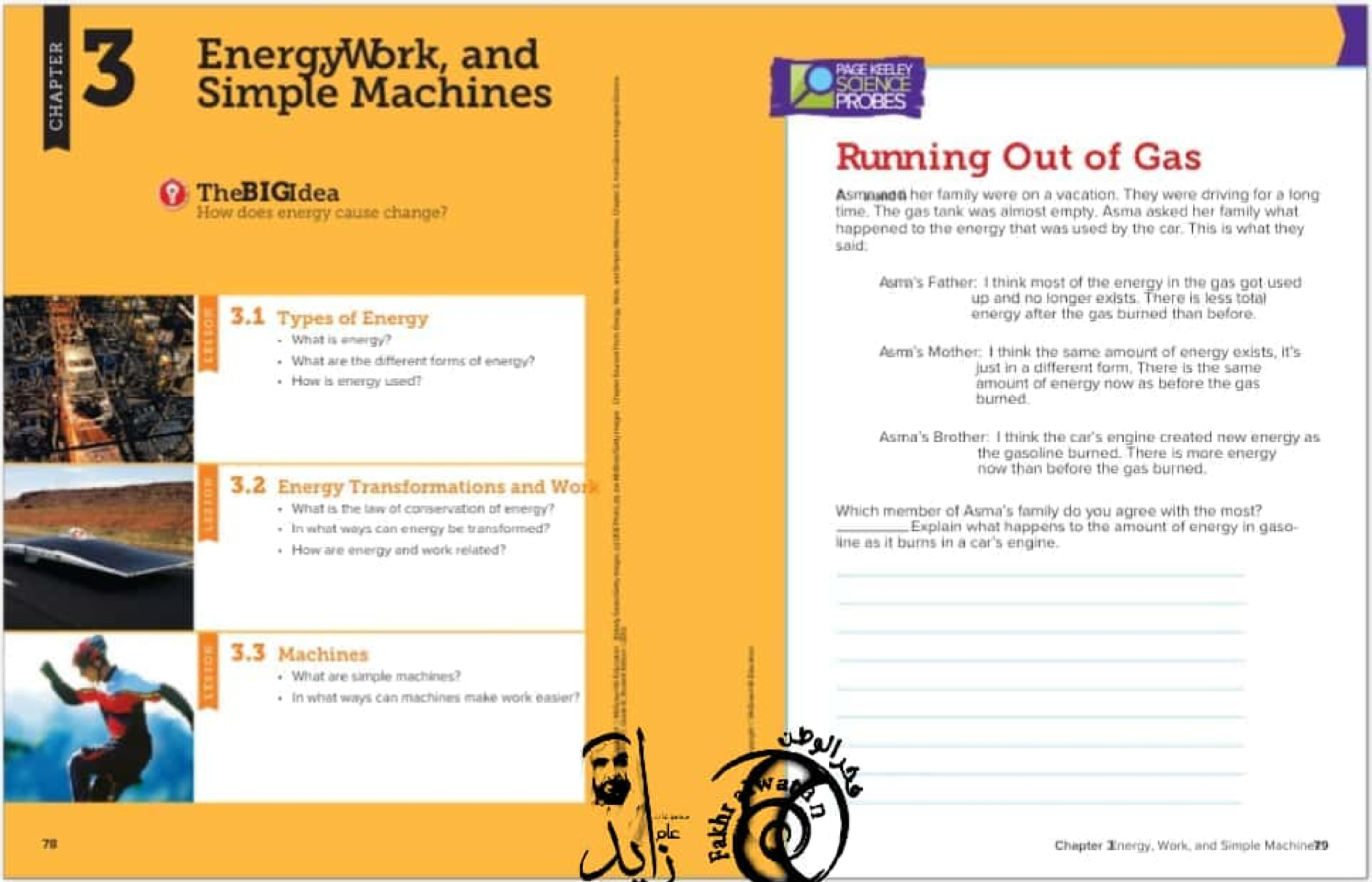

CHAPTER 3

Energy, Work, and Simple Machines

The BIG Idea
How does energy cause change?

LESSON 3.1 Types of Energy
- What is energy?
- What are the different forms of energy?
- How is energy used?

LESSON 3.2 Energy Transformations and Work
- What is the law of conservation of energy?
- In what ways can energy be transformed?
- How are energy and work related?

LESSON 3.3 Machines
- What are simple machines?
- In what ways can machines make work easier?

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Running Out of Gas

Asma and her family were on a vacation. They were driving for a long time. The gas tank was almost empty. Asma asked her family what happened to the energy that was used by the car. This is what they said:

Asma's Father: I think most of the energy in the gas got used up and no longer exists. There is less total energy after the gas burned than before.

Asma's Mother: I think the same amount of energy exists, it's just in a different form. There is the same amount of energy now as before the gas burned.

Asma's Brother: I think the car's engine created new energy as the gasoline burned. There is more energy now than before the gas burned.

Which member of Asma's family do you agree with the most? ________ Explain what happens to the amount of energy in gasoline as it burns in a car's engine.

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Energy, Work, and Simple Machines

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL What do you think of when you hear the word *energy*?	*Students may describe different types of energy, such as light energy, kinetic energy, or electric energy, or they may discuss how they expend energy when they work or play, among other possibilities.*
OL How do you think energy makes things happen?	*Students may explain that energy provides the power needed to make things happen. For example, food we eat contains the energy we need for growth, thermal energy cooks food, electric energy runs CD players, and so on.*
BL How do you think energy is related to work?	*Students may explain that energy provides the power needed to do work. For example, food we eat contains the energy we need to perform activities, such as reading, writing, exercising, and all of our bodies' internal processes.*

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Running Out of Gas

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and pre-conceptions about energy, work, and simple machines. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should feel comfortable to change any of their responses.

Anticipation Set for Lesson 1

1. **Energy is the ability to produce motion.**

   Disagree Only kinetic energy involves motion. Potential energy is stored energy due to the interaction of atoms, particles, or objects.

2. **Waves transfer energy from place to place**

   Agree Waves transfer only energy from place to place, not matter.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* People burn fuels, such as wood, oil, or natural gas, or use electricity to cook their food and to warm their houses.

* The Sun warms the land, air, and water.

* Changes in speed or direction are caused by forces.

* Moving air and water can be used to run machines.

* The greater the force is, the greater the change in motion will be.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

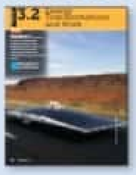
Lesson 1 Types of Energy

1 Energy is the ability to cause change.

2 Kinetic energy is the energy of objects in motion, including electric energy. The forms of potential energy include gravitational potential energy, chemical energy, and nuclear energy. Thermal energy and mechanical energy are forms of energy involving both kinetic and potential energies.

3 Energy is use[illegible] cars, heat homes, produce light, move muscles, cat[illegible] cook food, among many other examples.

Lesson 2 Energy Transformations and Work



4 The law of conservation of energy states that energy can be transformed from one form to another but it can never be created or destroyed.

5 Energy can be transformed from one form to another in a variety of ways.

6 Doing work on an object transfers energy to the object.

Lesson 3 Machines

7 Simple machines do work using one movement.

8 Machines make work easier by changing the size of the force required, the distance over which the object moves, or the direction of the input and output forces.

Identifying Misconceptions

Conservation of Energy

Find Out What Students Think

Students may think that...

... energy is created at power plants. They may not fully understand that one source of energy, such as wind power or water power, is transformed into another—in this case electricity.

Discussion

Engage in a conversation about the characteristics of different types of power plants and how they transform energy. Students will study various types of power plants in **Lesson 1**. **Ask:** Can you name a type of power plant? Write responses on the board as students provide answers. Responses may include **hydroelectric plant, a fossil fuel plant, and a nuclear plant.** Then, for each plant type, ask the following questions.

Ask: How is it different from other power plants? **Sample answer: It runs on coal instead of wind power or another form of energy.**

Ask: What is source of the electricity that is generated at that plant? **It comes from burning coal.**

Write students' answers on the board. Draw lines between the type of power plant and its energy source. Once the energy source is listed for each type of plant, ask students to think about how power plants are similar. Discuss the idea that all power plants use an energy source to generate or produce power; they don't create it in a vacuum.

Ask: What does the law of conservation of energy state? **Energy cannot be created or destroyed. It can only be transformed from one form to another.**

Ask: How does that apply to what happens at power plants? **At power plants, one type of energy, such as the chemical energy stored in coal, is transformed into electric energy.**

Promote Understanding

Activity Have students research one kind of power plant on the Internet or at the school library. Ask them to write a brief two-page report about it. Their reports should identify the type of power plant, briefly explain how it works, and include a diagram or illustration of the plant. Students should determine if and why the plant relies on a renewable or nonrenewable resource. For help selecting which plant they want to further research, refer them to the images of power plants from **Lesson 1**.

Machines and Forces

Find Out What Students Think

Students may think that...

... simple machines exert forces on objects but objects don't exert equal forces on simple machines. They might not understand Newton's third law of motion and how it relates to machines.

Discussion

Explain that when you press your hand against a desk, the desk presses back. Otherwise, the force of your hand would drive the desk into the floor.

The same thing happens when you use screwdrivers, hammers, and other kinds of simple or complex machines. These tools exert forces on objects; however, objects exert equal forces on hammers, screwdrivers, and other machines. Explain to students that when you turn a screw with a screwdriver, the screwdriver you use applies a force on the screw. The screw also exerts a force on the screwdriver, which helps the screw stay in place as you turn it. Remind students about Newton's laws of motion, which explain how forces act on objects and result in motion.

Ask: What is Newton's third law of motion? **If one object exerts a force on another object, the second object exerts an equal and opposite force on the first object.** **Ask:** How does Newton's third law of motion explain how forces interact when you turn a screw with a screwdriver? **The screwdriver exerts a force on the screw, and the screw exerts an equal and opposite force on the screwdriver.**

Promote Understanding

Activity Have students perform a task similar to the one shown in **Figure 20**. Provide them with small hammers, boards, thumbtacks, and safety glasses.

1. Explain that the students, hammers, thumbtacks, and boards all exert forces.
2. Have students work in pairs or small groups and take turns hammering thumbtacks into the boards. Ask them to describe the forces they feel.
3. **Ask:** Use Newton's third law of motion to explain how forces interact when you hammer a thumbtack. **The hammer exerts a force on the thumbtack, and the thumbtack exerts an equal and opposite force on the hammer.**
4. Ask them to create a diagram similar to **Figure 20** to show the different forces at work. They should include the force of:
    - the hand on the hammer,
    - the hammer on the hand,
    - the hammer on the thumbtack,
    - the thumbtack on the hammer,
    - the thumbtack on the board, and
    - the board on the thumbtack.

PAGE KEELEY SCIENCE PROBES

LESSON **3.1** Types of Energy

Explore Activity

Where does energy come from?

How can you warm your hands when they are cold? You could rub them together, put them in your pockets, or hold them near a heater. What makes your hands get warm?

1. Read and complete a lab safety form.
2. As you complete each of the following steps, observe and record any changes in your Science Journal. Discuss the changes with your lab group. In each case, ask: What caused this change to occur? Record your ideas.
3. Rub your hands together. What do you feel?
4. Use a match to light a candle. Holding your hands near the flame, what do you see and feel? *Use caution around an open flame.*
5. Turn on a **flashlight**. Where did the light come from?
6. Observe the overhead lights in your classroom. What is the source of the light?

Think About This

1. Where did the light and the heat come from in steps 3, 4, 5, and 6?
2. **Key Concept** How many different sources of energy can you recall? Briefly explain each one and tell how they differ from one another.

Essential Questions

- What is energy?
- What are the different forms of energy?
- How is energy used?

Vocabulary

energy
kinetic energy
electric energy
potential energy
chemical energy
nuclear energy
mechanical energy
thermal energy
sound energy
seismic energy
radiant energy

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INQUIRY

About the Photo Robots? This image shows an assembly line at an automobile factory. Today, many factories utilize robots to do repetitive tasks, such as welding and drilling. This image also illustrates several examples of energy, including electric energy, thermal energy, and kinetic energy. Have students discuss some of the examples of energy transformations from this photo.

Guiding Questions

AL What is one way that energy changes in this photo?	*Sample answer: Electric energy operates the robots and makes them move, which is an example of mechanical energy.*
OL Name two examples of energy transformations from this photo.	*Sample answer: As the robots work, the electric energy not only transforms into thermal energy, but also it changes into light energy and sound energy.*
BL What is an example of an energy transformation that you might find in a factory where workers assemble bicycles?	*Sample answer: The workers get energy from the food they eat, which transforms to kinetic energy as they put bicycle parts together.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Brainstorm a List of Related Terms

1. Record the vocabulary terms on the board or a large sheet of paper.
2. Ask students to read them and think about which terms or words they have heard before.
3. Students are likely to be familiar with a number of words, including *electric, chemical,* and *mechanical*. Ask them to brainstorm a list of related words for the vocabulary terms that they already know. For example, they may mention *current* or *circuit* for *electric energy*.
4. As students read the lesson's pages, ask them to brainstorm a list of related words for the vocabulary terms that they did not know

5. You may wish to add additional related terms to both lists as they read or create links between vocabulary terms.
6. Use this list to review vocabulary at the end of the chapter by creating sentences that link the vocabulary words to the related words. *Example: Electric energy relies on a circuit that carries a current.*

Teacher Notes

Explore Activity

Where does energy come from?

Prep *5 min* **Class** *20 min*

Purpose
Students observe and identify different types of energy and their sources.

Materials
Per student team birthday candle, small ball of clay, match, flashlight

Before You Begin
Demonstrate how to set the candle into the clay. Caution students to be careful with lit matches and candles and make sure they extinguish them completely.

Ask students to brainstorm types and sources of energy.

Draw a data table like the one below on the board. Have the students copy it into their Science Journals and use it to record their observations.

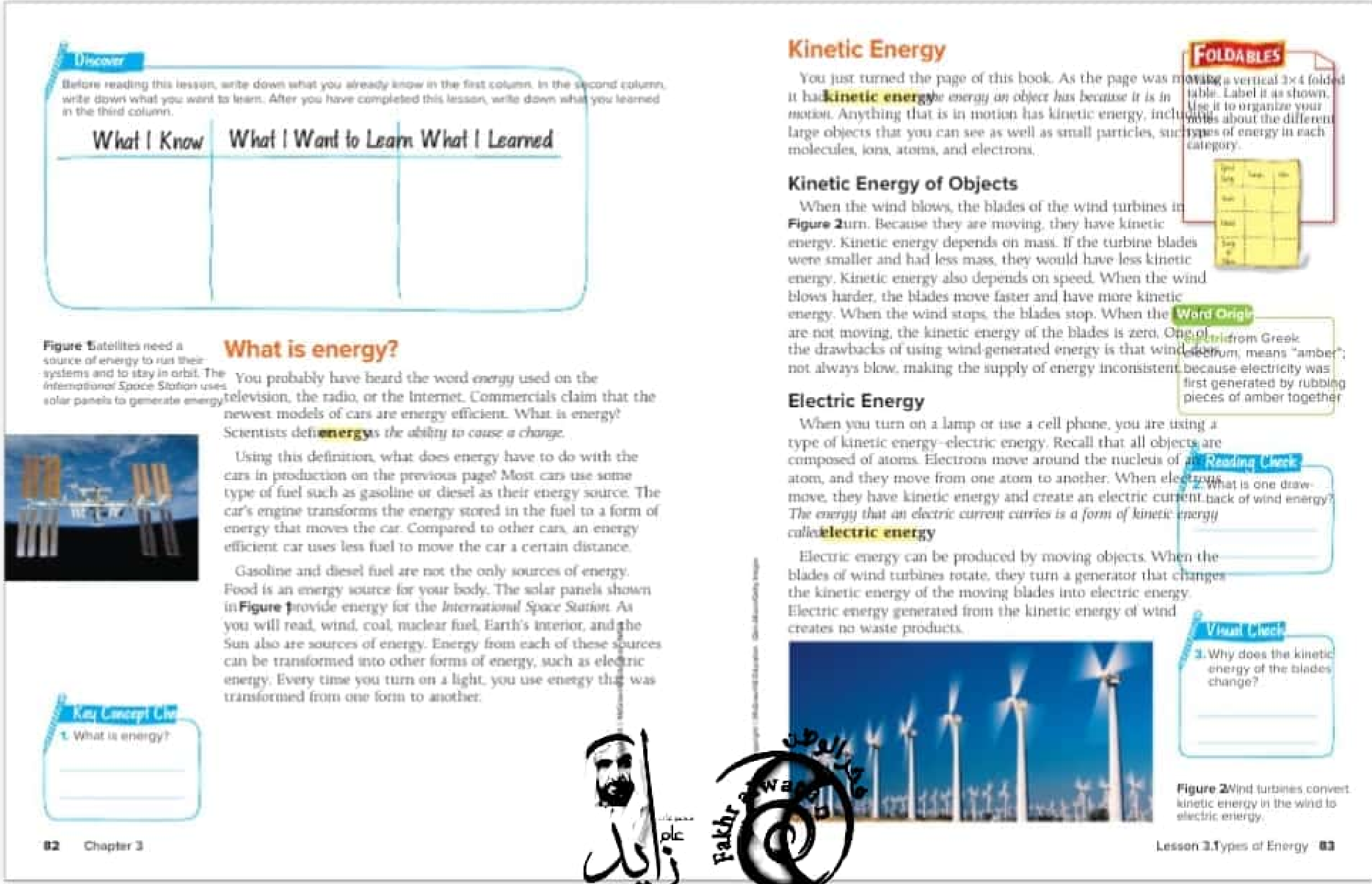
Situation	Observations	Energy Source
Rubbing hands		
Candle		
Flashlight		
Overhead lights		

Guide the Investigation
- Encourage students to try rubbing their hands together slowly and then faster to observe the difference.
- Monitor discussions. Prompt students to go beyond their first ideas about the source. For example, they may say that the source of the light in the overhead lights is electricity. Ask: **What is the source of the electricity?**
- Extend discussions by asking what source of energy causes an earthquake, powers a car, or produces sound?

Think About This
Students may not know the answers to all questions. Encourage them to hypothesize.

1. Students may suggest that the heat in their hands came from the movement of them, the heat and light from the candle came from burning it, that the light from the flashlight came from energy in the batteries, and that the light from the overhead lamps came from electricity.

2. **Key Concept** Answers may vary. Students might list thermal energy, radiant or light energy, and sound energy. They might say that the forms of energy are used in different ways.



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Figure 1 Satellites need a source of energy to run their systems and to stay in orbit. The *International Space Station* uses solar panels to generate energy.

What is energy?

You probably have heard the word *energy* used on the television, the radio, or the Internet. Commercials claim that the newest models of cars are energy efficient. What is energy? Scientists define **energy** as *the ability to cause a change.*

Using this definition, what does energy have to do with the cars in production on the previous page? Most cars use some type of fuel such as gasoline or diesel as their energy source. The car's engine transforms the energy stored in the fuel to a form of energy that moves the car. Compared to other cars, an energy efficient car uses less fuel to move the car a certain distance.

Gasoline and diesel fuel are not the only sources of energy. Food is an energy source for your body. The solar panels shown in **Figure 1** provide energy for the *International Space Station.* As you will read, wind, coal, nuclear fuel, Earth's interior, and the Sun also are sources of energy. Energy from each of these sources can be transformed into other forms of energy, such as electric energy. Every time you turn on a light, you use energy that was transformed from one form to another.

Key Concept Check

1. What is energy?

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Kinetic Energy

You just turned the page of this book. As the page was moving, it had **kinetic energy**—*the energy an object has because it is in motion.* Anything that is in motion has kinetic energy, including large objects that you can see as well as small particles, such as molecules, ions, atoms, and electrons.

FOLDABLES

Make a vertical 3×4 folded table. Label it as shown. Use it to organize your notes about the different types of energy in each category.

Kinetic Energy of Objects

When the wind blows, the blades of the wind turbines in **Figure 2** turn. Because they are moving, they have kinetic energy. Kinetic energy depends on mass. If the turbine blades were smaller and had less mass, they would have less kinetic energy. Kinetic energy also depends on speed. When the wind blows harder, the blades move faster and have more kinetic energy. When the wind stops, the blades stop. When the blades are not moving, the kinetic energy of the blades is zero. One of the drawbacks of using wind-generated energy is that wind does not always blow, making the supply of energy inconsistent.

Word Origin

electric from Greek *electrum,* means "amber"; because electricity was first generated by rubbing pieces of amber together

Electric Energy

When you turn on a lamp or use a cell phone, you are using a type of kinetic energy—electric energy. Recall that all objects are composed of atoms. Electrons move around the nucleus of an atom, and they move from one atom to another. When electrons move, they have kinetic energy and create an electric current. *The energy that an electric current carries is a form of kinetic energy called* **electric energy**.

Reading Check

2. What is one drawback of wind energy?

Electric energy can be produced by moving objects. When the blades of wind turbines rotate, they turn a generator that changes the kinetic energy of the moving blades into electric energy. Electric energy generated from the kinetic energy of wind creates no waste products.

Visual Check

3. Why does the kinetic energy of the blades change?

Figure 2 Wind turbines convert kinetic energy in the wind to electric energy.

Lesson 3.1 Types of Energy 83

What is energy?

Remind students that matter is anything that has mass and takes up space. Energy does not take up space; it affects matter. Have students read the section and **Figure 1**. Ask these questions to assess their understanding.

Guiding Questions

AL What is the energy source of a car?	*The energy source of a car is a fuel, such as gasoline.*
OL What is energy?	*Energy is the ability to cause a change.*

Kinetic Energy

Obtain several images of objects in motion from newspapers, magazines, or the Internet. Some possibilities include an athlete throwing a ball, a vehicle being driven down a road, a person jumping rope, a dog carrying a bone, and so on. Hold up the images for students to observe. Ask them to describe how things are changing in each image. Then have them read the paragraph and answer the following questions.

Guiding Questions

AL What is kinetic energy?	*Kinetic energy is the energy an object has because it is in motion.*
OL Give an example of kinetic energy.	*Sample answers: opening a book, lifting a pencil, driving a car*
BL Is running a lawn mower an example of kinetic energy? Why or why not?	*Yes, because it involves the energy of objects in motion, such as the blades on the mower or the grass that is cut.*

Kinetic Energy of Objects

Have students read the paragraph and study the **Figure 2**. Then ask the following questions to informally assess their understanding.

Guiding Questions

OL Why does the kinetic energy of the blades change?	*The kinetic energy of the blades changes because the speed of the blades changes.*
OL What two things does kinetic energy depend on?	*Kinetic energy depends on mass and speed.*
OL What is one drawback of wind energy?	*It can be inconsistent because wind does not always blow at the same rate and sometimes does not blow at all.*

Electric Energy

Explain that the electricity we use in our homes and schools comes from one or more power plants. The plant transforms one form of energy into electric energy. Many power plants burn coal to generate electricity. Others use energy from the wind or the Sun. Have students read the paragraph and explain electric energy in their own words. Their definition should note that *electric energy is the energy that is carried by an electric current.*

Word Origin

electric

Have students read the Greek origin of the word *electric*. Explain that an ancient Greek philosopher discovered that when he rubbed a piece of amber with a cloth, it became electrically charged due to friction, and feathers and other objects stuck to it.

Differentiated Instruction

AL **In Your Own Words** Have students rewrite the caption for **Figures 2** and **3** in their own words. They should includ the terms *kinetic energy* and *potential energy* in their captions. They should also explain how each image is a example of energy.

BL **Draw a Diagram** Have students research how a powe plant works and draw a diagram of it. They should inclu the source of energy used to generate electricity and indicate how that form of energy is collected, such as w turbines outside a wind-generated energy facility or a d at a hydroelectric plant.

Teacher Toolbox

Reading Strategy

What's the Main Idea? Have students record the main idea for each section that begins with a red heading. They should also include a few sentences with important det For example, for the first section, they should define *en* and explain that there are several different types.

Teacher Demo

Energy Pluses and Minuses Get students thinking about the benefits and challenges of different types of energy listing them on chart paper or the board.

1. Across the top of the list write *Energy*.
2. As you work through the lesson, write the name of th type of energy, classify it as kinetic, potential, or wav energy. Then list one benefit and one challenge of u it as an energy source. Examples of energy types list

Electric energy from wind turbines	kinetic	clean but inconsistent
Hydroelectric energy from dams	potential	clean but can cause disrupted course of nature

Potential Energy

Suppose you hold up a piece of paper. When the paper is held above the ground, it has potential energy. **Potential energy** *stored energy that depends on the interaction of objects, particles, or atoms*

Gravitational Potential Energy

Gravitational potential energy is a type of potential energy stored in an object due to its height above Earth's surface. The water at the top of the **Figure 3** has gravitational potential energy. Gravitational potential energy depends on the mass of an object and its distance from Earth's surface. The more mass an object has and the greater its distance from Earth, the greater its gravitational potential energy.

In a hydroelectric energy plant, water above a dam flows through turbines as it falls. Generators connected to the spinning turbines convert the gravitational potential energy of the water into electric energy.

Hydroelectric power plants are a very clean source of energy. About 7 percent of all electric power in the United States is produced from hydroelectric energy. However, hydroelectric plants can interrupt the movement of animals in streams and rivers.

Reading Check
4. What is chemical energy?

Figure 3 Hydroelectric energy plants use the gravitational potential energy stored in water to produce electricity.

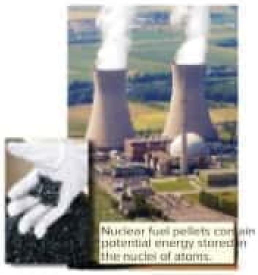


Figure 4 Chemical energy and nuclear energy are two forms of potential energy.

Chemical Energy

Most electric energy in the United States comes from fossil fuels such as petroleum, natural gas, and coal. The atoms that make up these fossil fuels are joined by chemical bonds. Chemical bonds have the potential to break apart. Therefore, chemical bonds have a form of potential energy called chemical energy. **Chemical energy** *energy that is stored in and released from the bonds between atoms.*

When fossil fuels burn, the chemical bonds between the atoms that make up the fossil fuel break apart. When this happens, chemical energy transforms to thermal energy. This energy is used to heat water and form steam. The steam is used to turn a turbine, which is connected to a generator that generates electric energy.

A drawback of fossil fuels is that they introduce harmful waste products, such as sulfur dioxide and carbon dioxide, into the environment. Sulfur dioxide in the air creates acid [illegible]. Most scientists suspect that increased [illegible] carbon dioxide in the atmosphere contribute[illegible] to climate change. Scientists are [illegible] replacement fuels that do not [illegible] the environment.

Fossil fuels are not the only source of chemical energy. Chemical energy also is stored in the foods you eat. Your body converts the energy stored in chemical bonds in food into the kinetic energy of your moving muscles and into the electric energy that sends signals through your nerves to your brain.

Nuclear Energy

The majority of energy on Earth comes from the Sun. A process, called nuclear fusion, in the Sun joins the nuclei of atoms and, in the process, releases large amounts of energy. On Earth, nuclear energy plants, such as the one shown in **Figure 4**, break apart the nuclei of certain atoms using a process called nuclear fission. Both nuclear fusion and nuclear fission release **nuclear energy** *energy stored in and released from the nucleus of an atom*

Nuclear fission produces a large amount of energy from just a small amount of fuel. However, the process produces radioactive waste that is hazardous and difficult to dispose of safely.

Potential Energy

Gravitational Potential Energy

Explain that water is another source of energy that is often used to generate electricity. Then ask your students the following questions.

Guiding Questions

AL What is gravitational potential energy?	*Gravitational potential energy is stored energy that depends on the position of an object relative to Earth's surface.*
OL What are two things gravitational potential energy depends on?	*Gravitational potential energy depends on position and mass.*
BL Does a book hanging off a table edge have gravitational potential energy? Why or why not?	*Yes, because the book has mass and is above Earth's surface.*

Chemical Energy

Have students discuss their experiences with the **Launch Lab**. Ask them what were the sources of the energy for the light and the heat *(the battery and the match)*. Explain that batteries and matches are examples of stored chemical energy. When you strike the match, a chemical reaction occurs that transforms the stored energy to thermal energy. When you turn on the light, a chemical reaction occurs inside the battery that transforms the stored chemical energy to electric energy, which transforms to light energy. Then have the students read the paragraphs and answer the following questions.

Guiding Questions

AL What kind of energy is stored in food?	*The energy stored in food is chemical energy.*
OL What is chemical energy?	*Chemical energy is the energy that is stored in the bonds between atoms.*
OL Where is energy stored in fossil fuels?	*The energy in fossil fuels is stored in the bonds between carbon atoms.*
BL Name a material, other than fossil fuels, that is burned to release chemical energy.	*Sample answers: wood, paper*

Nuclear Energy

Have students compare the images of coal and nuclear fuel pellets in **Figure 4**. Explain that both are examples of stored energy and can be used to generate electricity. Then have students read the paragraphs. Ask the following questions to informally assess their comprehension.

Guiding Questions

AL What is nuclear energy?	*Nuclear energy is energy that is stored in and released from an atom's nucleus.*
OL What is nuclear fusion?	*Nuclear fusion is a process in which the nuclei of atoms are joined together, releasing large amounts of energy.*
BL In what way might nuclear energy be more beneficial than other forms of energy? In what way might nuclear energy be less beneficial than other forms of energy?	*Nuclear energy can generate a lot of electricity from a small amount of fuel, which might make it more beneficial than other forms of energy. However, this process can result in dangerous radioactive waste, which makes it more hazardous to produce than other forms of energy.*

Differentiated Instruction

AL **Create a Poster** Have students work in pairs to make poster that shows different examples of energy source Some possibilities include coal, gasoline, wood, paper, the Sun. They can create illustrations or find images in magazines or on the Internet. Students should label ea energy source and identify the type of energy it repres such as chemical energy, solar energy, and so on.

BL **Make a Brochure** Ask students to make a brochure advertising a certain type of energy source, such as fo fuels or wind energy. They should identify the energy source and explain how it is used and how it benefits consumers.

Teacher Toolbo

Reading Strategy

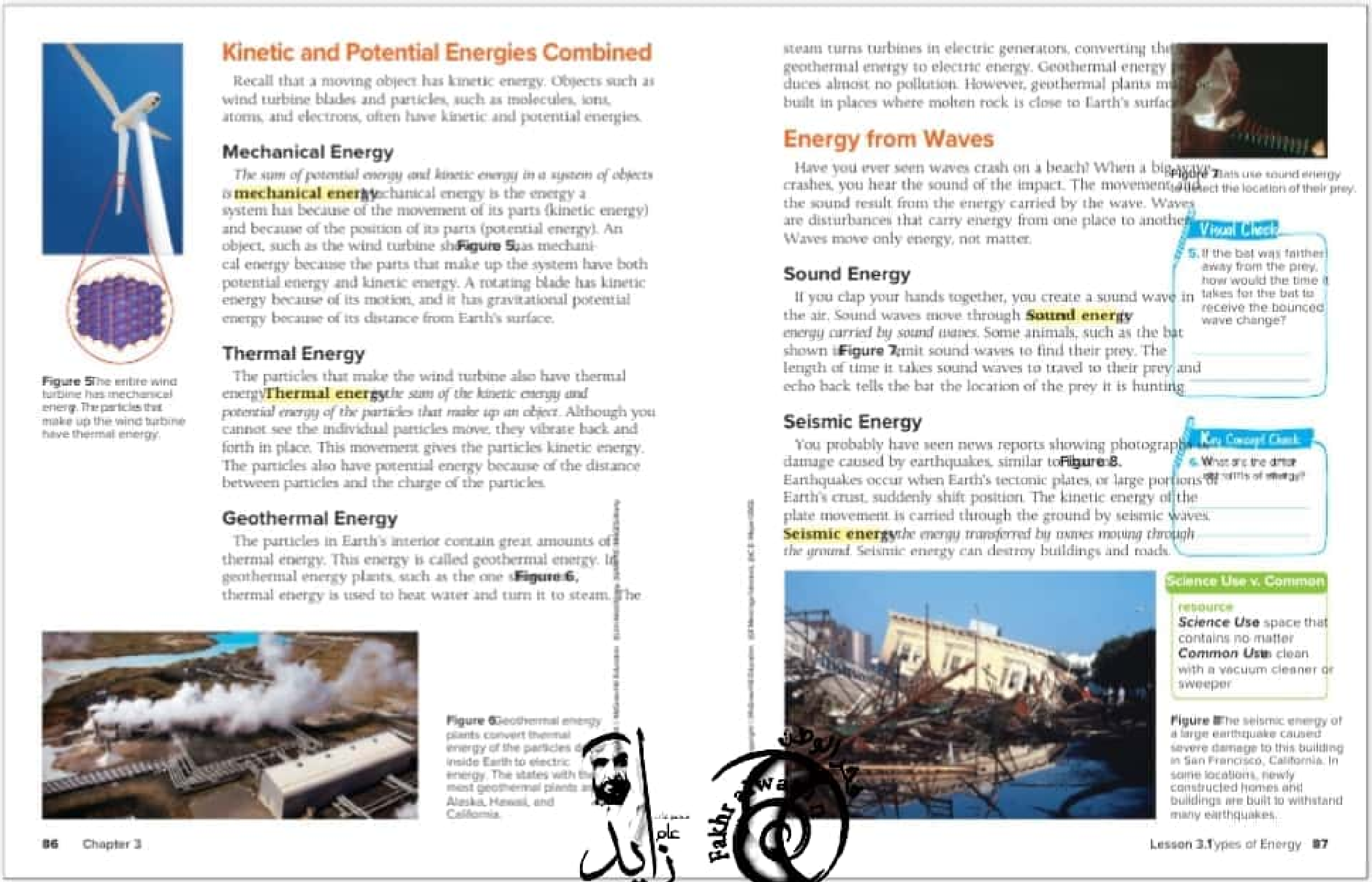
Compare/Contrast Have students write a short compare-and-contrast paragraph on chemical and nuclear energ They should explain that both cause change and are examples of stored energy. One is stored in bonds between atoms, whereas the other is stored in the nuc of an atom.

Fun Fact

What is temperature? Temperature is not the same as thermal energy. Every object is made of particles that always in motion. Temperature describes the average kinetic energy of these particles. The faster particles m the greater the kinetic energy and the higher the temperature. Increasing thermal energy speeds up pa and increases temperature, whereas decreasing therm energy slows down particles and decreases temperatu

Real-World Science

Energy from the Sun The Sun is a major source of energ Energy from sunlight helps plants grow and is stored i them as chemical energy. It is also the source of energ in wood and fossil fuels, two other examples of chemi energy. The Sun itself is an example of nuclear energy Energy released from hydrogen atoms gives the Sun its power.



Kinetic and Potential Energies Combined

Recall that a moving object has kinetic energy. Objects such as wind turbine blades and particles, such as molecules, ions, atoms, and electrons, often have kinetic and potential energies.

Mechanical Energy

The sum of potential energy and kinetic energy in a system of objects is **mechanical energy**. Mechanical energy is the energy a system has because of the movement of its parts (kinetic energy) and because of the position of its parts (potential energy). An object, such as the wind turbine shown in **Figure 5**, has mechanical energy because the parts that make up the system have both potential energy and kinetic energy. A rotating blade has kinetic energy because of its motion, and it has gravitational potential energy because of its distance from Earth's surface.

Figure 5 The entire wind turbine has mechanical energy. The particles that make up the wind turbine have thermal energy.

Thermal Energy

The particles that make the wind turbine also have thermal energy. **Thermal energy** *is the sum of the kinetic energy and potential energy of the particles that make up an object.* Although you cannot see the individual particles move, they vibrate back and forth in place. This movement gives the particles kinetic energy. The particles also have potential energy because of the distance between particles and the charge of the particles.

Geothermal Energy

The particles in Earth's interior contain great amounts of thermal energy. This energy is called geothermal energy. In geothermal energy plants, such as the one shown in **Figure 6**, thermal energy is used to heat water and turn it to steam. The steam turns turbines in electric generators, converting the geothermal energy to electric energy. Geothermal energy produces almost no pollution. However, geothermal plants must be built in places where molten rock is close to Earth's surface.

Figure 6 Geothermal energy plants convert thermal energy of the particles deep inside Earth to electric energy. The states with the most geothermal plants are Alaska, Hawaii, and California.

Energy from Waves

Have you ever seen waves crash on a beach? When a big wave crashes, you hear the sound of the impact. The movement and the sound result from the energy carried by the wave. Waves are disturbances that carry energy from one place to another. Waves move only energy, not matter.

Figure 7 Bats use sound energy to detect the location of their prey.

Sound Energy

If you clap your hands together, you create a sound wave in the air. Sound waves move through matter. **Sound energy** *is energy carried by sound waves.* Some animals, such as the bat shown in **Figure 7**, emit sound waves to find their prey. The length of time it takes sound waves to travel to their prey and echo back tells the bat the location of the prey it is hunting.

Visual Check

5. If the bat was farther away from the prey, how would the time it takes for the bat to receive the bounced wave change?

Seismic Energy

You probably have seen news reports showing photographs of damage caused by earthquakes, similar to **Figure 8**. Earthquakes occur when Earth's tectonic plates, or large portions of Earth's crust, suddenly shift position. The kinetic energy of the plate movement is carried through the ground by seismic waves. **Seismic energy** *is the energy transferred by waves moving through the ground.* Seismic energy can destroy buildings and roads.

Key Concept Check

6. What are the [illegible]

Science Use v. Common

resource

Science Use space that contains no matter

Common Use to clean with a vacuum cleaner or sweeper

Figure 8 The seismic energy of a large earthquake caused severe damage to this building in San Francisco, California. In some locations, newly constructed homes and buildings are built to withstand many earthquakes.

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Kinetic and Potential Energies Combined

Remind students about the difference between kinetic energy and potential energy. Kinetic energy is the energy of objects in motion, whereas potential energy is stored in objects, particles, or atoms. Have students name the different forms of energy they have studied so far and identify them as examples of kinetic energy or potential energy.

Mechanical Energy

Have students read the paragraph and study the image of a wind turbine in **Figure 5**. **Ask: What is mechanical energy?** *Mechanical energy is the sum of potential energy and kinetic energy in a system of objects.*

Thermal Energy

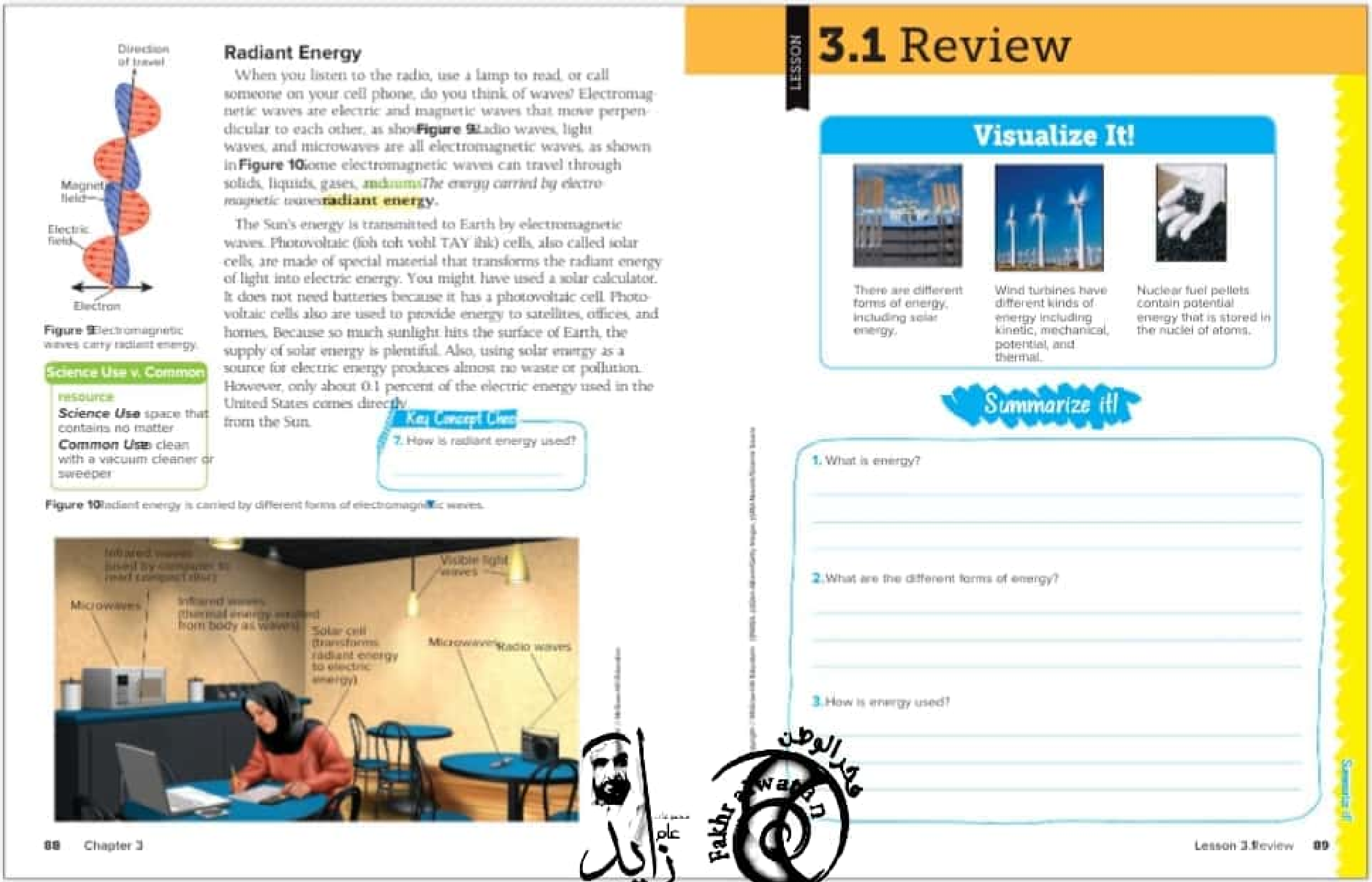
Remind students about their experience in the **Launch Lab**. Ask them to describe how their hands felt after they rubbed them together. Explain that this was an example of thermal energy. Ask students to name other examples of thermal energy. Then ask the following questions.

Guiding Questions

AL	What is thermal energy?	*Thermal energy is the sum of the kinetic and potential energies of the particles that make up an object.*
OL	What happens to the movement of particles in an object as thermal energy increases?	*The particles vibrate faster and/or the particles move farther apart.*
BL	Describe the difference between a cup of hot tea and a cup of iced tea in terms of thermal energy	*A cup of hot tea has a higher sum of the kinetic and potential energies of its particles than a cup of iced tea does.*
BL	Why does an entire wind turbine have mechanical energy, but the particles in a single blade do not?	*Mechanical energy is the sum of potential and kinetic energies in a system of particles. The wind turbine is a complete system, so it has mechanical energy. The individual particles in a single blade have thermal energy but not mechanical energy.*

Geothermal Energy

Have students read the paragraph and examine **Figure 6**. Explain that workers at geothermal plants drill deep into Earth to tap into sources of geothermal energy. It is found in magma, which is hot, liquid rock found beneath the planet's surface. Magma is also released from erupting volcanoes in the form of lava.


Radiant Energy

When you listen to the radio, use a lamp to read, or call someone on your cell phone, do you think of waves? Electromagnetic waves are electric and magnetic waves that move perpendicular to each other, as shown in **Figure 9**. Radio waves, light waves, and microwaves are all electromagnetic waves, as shown in **Figure 10**. Some electromagnetic waves can travel through solids, liquids, gases, and vacuums. *The energy carried by electromagnetic waves is* **radiant energy**.

The Sun's energy is transmitted to Earth by electromagnetic waves. Photovoltaic (foh toh vohl TAY ihk) cells, also called solar cells, are made of special material that transforms the radiant energy of light into electric energy. You might have used a solar calculator. It does not need batteries because it has a photovoltaic cell. Photovoltaic cells also are used to provide energy to satellites, offices, and homes. Because so much sunlight hits the surface of Earth, the supply of solar energy is plentiful. Also, using solar energy as a source for electric energy produces almost no waste or pollution. However, only about 0.1 percent of the electric energy used in the United States comes directly from the Sun.

Figure 9 Electromagnetic waves carry radiant energy.

Science Use v. Common Use
resource
Science Use space that contains no matter
Common Use to clean with a vacuum cleaner or sweeper

Key Concept Check
7. How is radiant energy used?

Figure 10 Radiant energy is carried by different forms of electromagnetic waves.

LESSON **3.1** Review

Visualize It!

There are different forms of energy, including solar energy.

Wind turbines have different kinds of energy including kinetic, mechanical, potential, and thermal.

Nuclear fuel pellets contain potential energy that is stored in the nuclei of atoms.

Summarize it!

1. What is energy?

2. What are the different forms of energy?

3. How is energy used?

Radiant Energy

Review how sound waves that travel parallel to each other and through matter carry sound energy and how waves that move through the ground carry seismic energy. Explain that the different types of electromagnetic waves move perpendicular to each other as they move through matter or a vacuum. Have students read the paragraph and study how different types of electromagnetic waves have different energy functions.

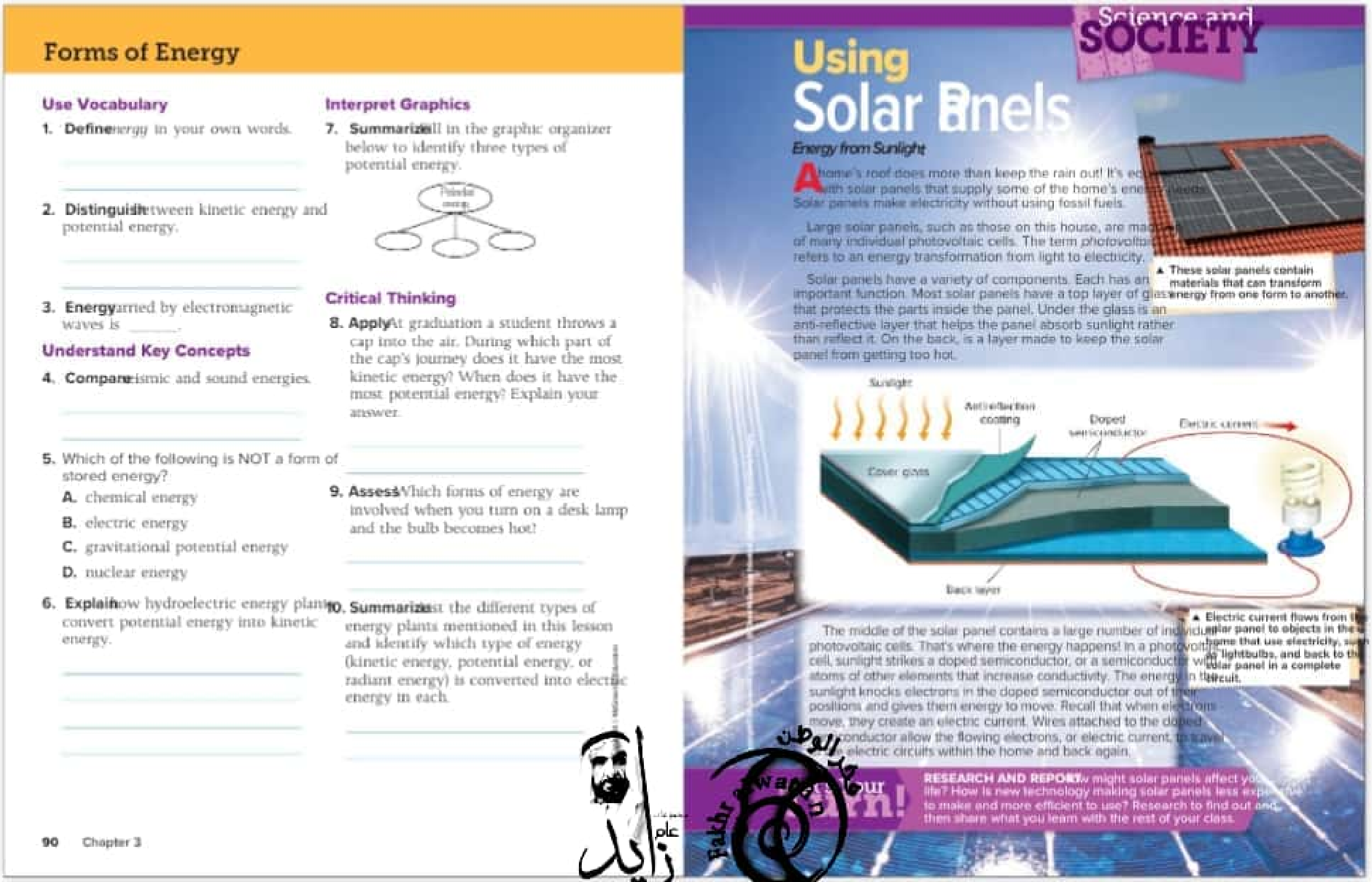
Guiding Questions

AL How does radiant energy travel?	*Radiant energy travels in the form of electromagnetic waves.*
OL Name one kind of radiant energy.	*Sample answers: radio waves, light waves, or microwaves*
OL How is radiant energy used?	*Sample answer: Radiant energy is used for many purposes including cooking food, lighting homes, heating and cooling homes, transporting people and products, and manufacturing products.*
BL Why is light from the Sun able to reach Earth?	*Light is carried by electromagnetic waves, which can travel through a vacuum, such as space.*

Visual Literacy: Figure 10

Have students refer to their reading of the section and examine **Figure 10** to answer the following questions. If students cannot answer the questions, reread the section together as you reference **Figure 9** and **Figure 10**. Clarify that although the radio, lamps, cell phone, and microwave might be powered by electricity, they are all emitting radiant energy.

Ask: **What kinds of waves are used by all the appliances shown?** *electromagnetic waves* **How are they formed?** *They are formed by electric and magnetic waves moving perpendicular to each other.*



Use Vocabulary

1. Sample answer: Energy is the ability to make things happen.
2. Kinetic energy is the energy of motion. Potential energy is the energy stored because of the interaction between objects, particles, or atoms.
3. radiant energy

Understand Key Concepts

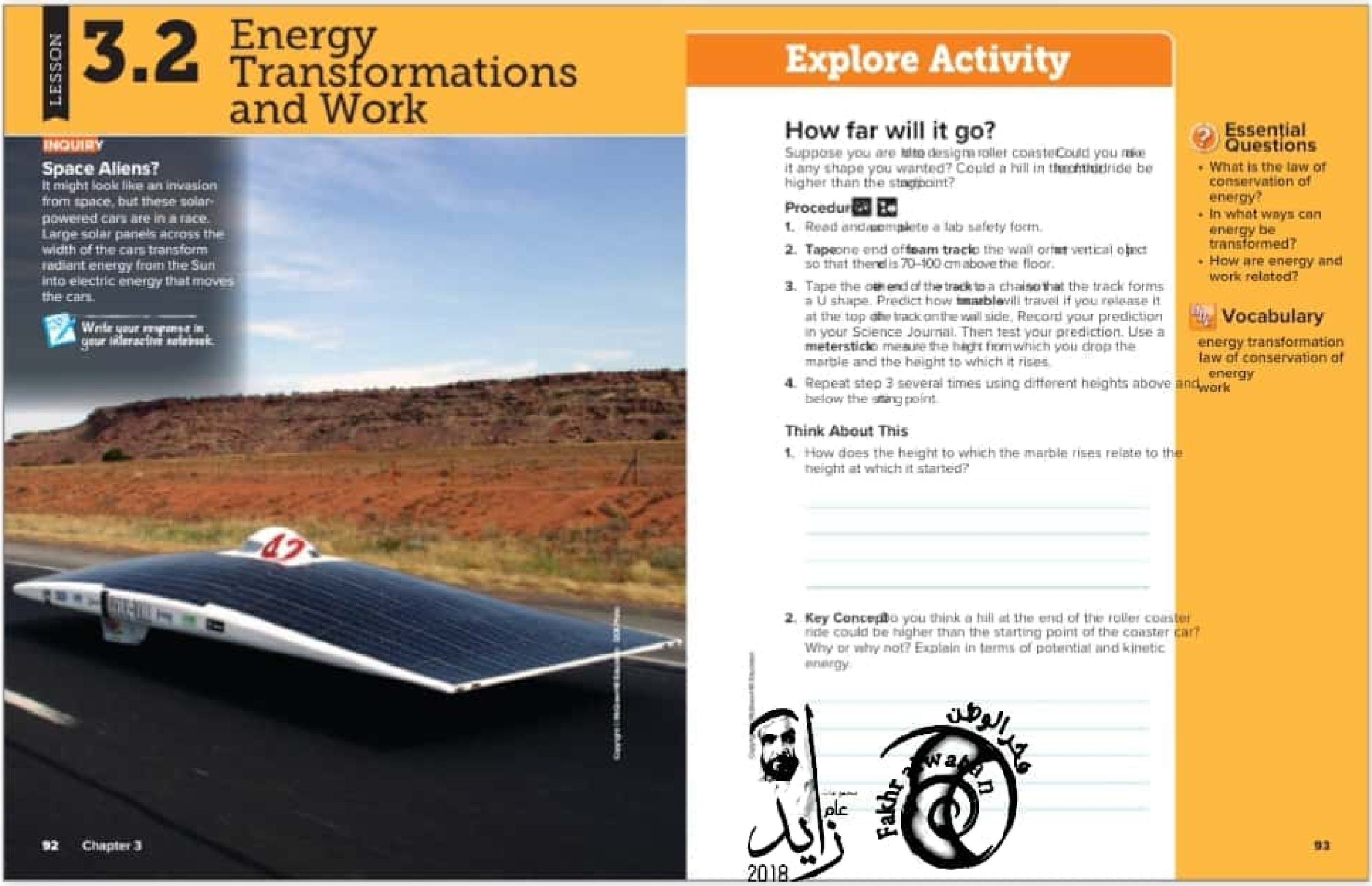
4. Both sound waves and seismic waves carry energy through material. Seismic waves specifically travel through Earth.
5. **B.** electric energy
6. Hydropower plants convert gravitational potential energy in water to kinetic energy by channeling the falling water into a turbine. The falling water causes the turbine to turn. The turbine transforms gravitational potential energy into kinetic energy.

Interpret Graphics

7. gravitational protential energy, chemical energy, nuclear energy (in any order)

Critical Thinking

8. It has the most kinetic energy just as it leaves the student's hand and just before it is caught. At these points, the cap has the greatest speed. It has the most potential energy just as it begins to fall back toward Earth. At the peak of its travel, all of the cap's kinetic energy has been transformed to potential energy.
9. Electric energy moves through the wire to the lamp's bulb. In the bulb's filament, electric energy transforms into thermal energy and light energy.
10. Geothermal plants: potential energy and kinetic energy (from turbines); Hydroelectric plants: potential energy and kinetic energy (from turbines); Fuelpowered electrical power plants: potential energy and kinetic energy (from turbines); Nuclear power plants: potential energy and kinetic energy (from turbines); Most power plants convert potential energy into kinetic energy then into electric energy.



LESSON 3.2 Energy Transformations and Work

INQUIRY

Space Aliens?

It might look like an invasion from space, but these solar-powered cars are in a race. Large solar panels across the width of the cars transform radiant energy from the Sun into electric energy that moves the cars.

Write your response in your interactive notebook.

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Explore Activity

How far will it go?

Suppose you are asked to design a roller coaster. Could you make it any shape you wanted? Could a hill in the middle of the ride be higher than the starting point?

Procedure

1. Read and complete a lab safety form.
2. **Tape** one end of a **foam track** to the wall or other vertical object so that the end is 70–100 cm above the floor.
3. Tape the other end of the track to a chair so that the track forms a U shape. Predict how far a **marble** will travel if you release it at the top of the track on the wall side. Record your prediction in your Science Journal. Then test your prediction. Use a **meterstick** to measure the height from which you drop the marble and the height to which it rises.
4. Repeat step 3 several times using different heights above and below the starting point.

Think About This

1. How does the height to which the marble rises relate to the height at which it started?
2. **Key Concept** Do you think a hill at the end of the roller coaster ride could be higher than the starting point of the coaster car? Why or why not? Explain in terms of potential and kinetic energy.

Essential Questions

- What is the law of conservation of energy?
- In what ways can energy be transformed?
- How are energy and work related?

Vocabulary

energy transformation
law of conservation of energy
work

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INQUIRY

About the Photo **Space Aliens?** Remind students about photovoltaic cells, which they learned about in the previous lesson. Explain that the vehicles in this photo also run on photovoltaic cells. Refer students to **Figure 1** at the beginning of **Lesson 1** and compare the solar cells on the satellite to the solar cells on these vehicles.

Guiding Questions

AL What kind of energy powers the cars in this photo?	*solar energy*
OL How do photovoltaic cells help power these cars?	*They capture sunlight and turn it into electric energy that moves the cars.*
BL When might it be difficult to drive these cars?	*It might be difficult on a rainy or cloudy day when there is little sunlight.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

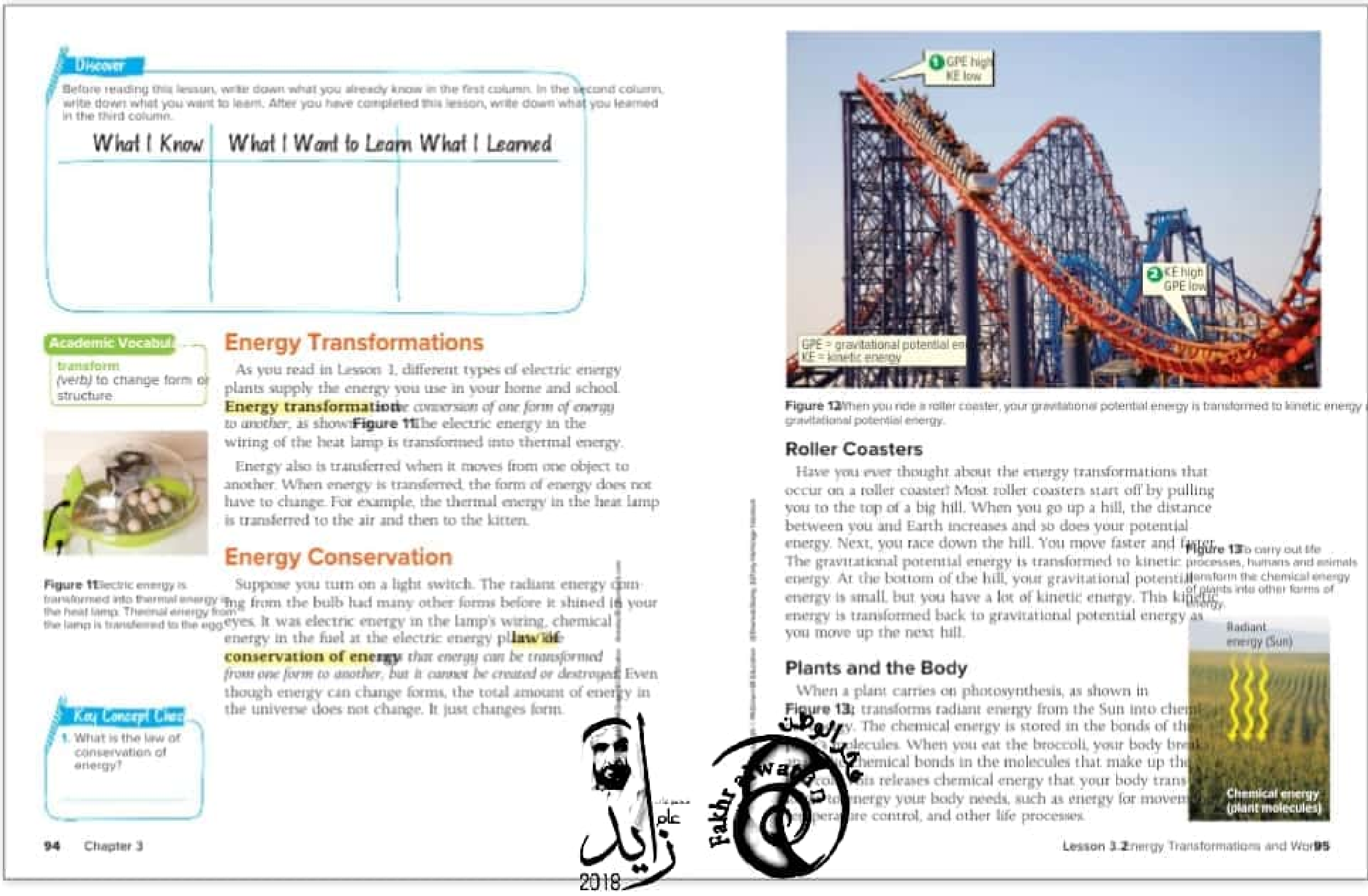
After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Identify Examples of Energy Use

Prepare students to understand the law of conservation of energy and energy transformations by completing this background knowledge activity.

1. Have students name some examples of energy use, such as cooking food or turning on a lamp. Write a list of all the uses of energy they name on chart paper or on the board.
2. Ask students to group all the different forms of energy by type. For example, cooking food is an example of thermal energy, and turning on a lamp is an example of light energy.



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Academic Vocabulary

transform

(verb) to change form or structure

Energy Transformations

As you read in Lesson 1, different types of electric energy plants supply the energy you use in your home and school. **Energy transformation** is the conversion of one form of energy to another, as shown in **Figure 11**. The electric energy in the wiring of the heat lamp is transformed into thermal energy.

Energy also is transferred when it moves from one object to another. When energy is transferred, the form of energy does not have to change. For example, the thermal energy in the heat lamp is transferred to the air and then to the kitten.

Figure 11 Electric energy is transformed into thermal energy in the heat lamp. Thermal energy from the lamp is transferred to the eggs.

Energy Conservation

Suppose you turn on a light switch. The radiant energy coming from the bulb had many other forms before it shined in your eyes. It was electric energy in the lamp's wiring, chemical energy in the fuel at the electric energy plant. The **law of conservation of energy** *says that energy can be transformed from one form to another, but it cannot be created or destroyed.* Even though energy can change forms, the total amount of energy in the universe does not change. It just changes form.

Key Concept Check

1. What is the law of conservation of energy?

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Figure 12 When you ride a roller coaster, your gravitational potential energy is transformed to kinetic energy and back to gravitational potential energy.

Roller Coasters

Have you ever thought about the energy transformations that occur on a roller coaster? Most roller coasters start off by pulling you to the top of a big hill. When you go up a hill, the distance between you and Earth increases and so does your potential energy. Next, you race down the hill. You move faster and faster. The gravitational potential energy is transformed to kinetic energy. At the bottom of the hill, your gravitational potential energy is small, but you have a lot of kinetic energy. This kinetic energy is transformed back to gravitational potential energy as you move up the next hill.

Figure 13 To carry out life processes, humans and animals transform the chemical energy of plants into other forms of energy.

Plants and the Body

When a plant carries on photosynthesis, as shown in **Figure 13**, it transforms radiant energy from the Sun into chemical energy. The chemical energy is stored in the bonds of the molecules. When you eat the broccoli, your body breaks the chemical bonds in the molecules that make up the broccoli. This releases chemical energy that your body transforms to energy your body needs, such as energy for movement, temperature control, and other life processes.

Lesson 3.2 Energy Transformations and Work 95

Energy Transformations / Energy Conservation

Have students read the paragraphs and **Figure 11**. Discuss how the heat lamp transforms electric energy into thermal energy to help warm the piglets.

Ask: What is the law of conservation of energy? *The law of conservation of energy says that energy can be transformed from one form to another, but it cannot be created or destroyed.*

Academic Vocabulary

transform

Have students read the definition of the word transform. **Ask: What is a synonym for the word transform?** *Sample answers: change, alter, mutate, convert*

Roller Coasters

Remind students about the ideas for roller coasters from the **Launch Lab**. Explain that if roller coasters have higher hills in the middle of the ride, additional energy must be added to the roller coaster. Then have students read the paragraph and study the image in **Figure 12**. Ask the following scaffolded questions to informally assess students' understanding.

Guiding Questions

AL What kind of energy transforms from gravitational potential energy as a roller coaster speeds down a hill?	*Kinetic energy transforms from gravitational potential energy as a roller coaster speeds down a hill.*
OL How does energy change as you ride a roller coaster?	*Kinetic energy transforms to gravitational potential energy as you ride up a hill, and gravitational potential energy transforms to kinetic energy as you ride down a hill.*
BL How do you think energy transforms as you ride through a loop on a roller coaster?	*Kinetic energy transforms to gravitational potential energy as you roll from the bottom of the loop to the top. Then the gravitational potential energy transforms to kinetic energy as you roll from the top back down to the bottom and out of the loop.*

Key Concept Check
2. Identify three energy transformations that occur to make electric energy.

Key Concept Check
3. If you do work on an object, how will its energy change?

Visual Check
4. What energy transformations occur as the drums are lifted?

Electric Energy Plants

About 300 million years ago, plants carried out photosynthesis, just like plants do today. These ancient plants stored radiant energy from the Sun as chemical energy in their molecular bonds. After they died, the plants became buried under sediment. After much time and pressure from the sediments above them, these plants turned into fossil fuels. When electric energy plants burn fossil fuels, they transform the chemical energy from the molecules that were made by plants that lived millions of years ago. That chemical energy is transformed to the electric energy that you use in your home and school.

As you read in Lesson 1, other forms of energy, such as solar, wind, geothermal, and hydroelectric energy, also are transformed to electric energy by electric energy plants.

Energy and Work

When you study for a test, do you do work? It might seem like it, but it would not be work as defined by **Work** *the transfer of energy that occurs when a force makes an object move in the direction of the force while the force acts on the object.* Recall that forces are pushes or pulls. When you lift an object, you transfer energy from your body to the object. As the boy lifts the **Figure 14** they move and have kinetic energy. As the drums get higher off the ground, they gain gravitational potential energy. The boy has done work on the drums.

Figure 14 The boy does work on the drums when he lifts them. Once the drums are in place, no work is being done.

On the right in Figure 14, the boy is standing still with the drums lifted in place. Because he is not moving the drums, he is not doing work. To do work on an object, an object must move in the direction of the force. Work is done only while the force is moving the object.

Word Origin
work from Greek ergon, means "activity"

Doing Work

How much **work** do you do when you lift your backpack off the ground? If you lift a backpack with a force of 20 N, you do less work than if you lift a backpack with a force of 40 N. Work depends on the amount of force applied to the object.

Work also depends on the distance the object moves during the time the force is applied. If you lift a backpack 1 m you do less work than if you lift it 2 m. Suppose you toss a backpack in the air. When you release it, it continues moving upward. Even though the backpack is still moving when you let go, no work is being done. This is because you are no longer applying a force to the backpack while it is in the air.

FOLDABLES
Create a vertical half-book. Label it as shown. Use it to summarize, in your own words, the relationship between work and energy.

Calculating Work

The equation for work is shown below. *Force* is the force applied to the object. Distance is the distance the object moves in the direction of the force while the force is acting on it.

Work Equation

work (in joules) = force (in newtons) × distance (in meters)

$$W = Fd$$

The force in the equation is in newtons (N), and distance is in meters (m). The product of newtons and meters is newton-meter (Nm). A newton-meter is also called a joule (J).

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Energy and Work

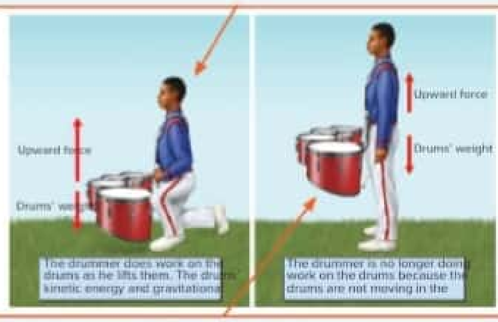
Ask students to define the word *work* in their own terms. Have them identify examples of work. For example, they may name examples of professions, such as working as a doctor or a lawyer, or they might identify specific tasks, such as housecleaning. Then have students read the first paragraph. Ask them to compare the class definition of work to the scientific definition of the term. Then have your students read the second paragraph and answer the following questions.

Guiding Questions

AL What is the scientific definition of work?	*Work is the transfer of energy that occurs when a force makes an object or a particle move.*
OL If you do work on an object, how will its energy change?	*Its energy will increase.*
BL How is putting a book in your bookbag an example of work?	*Possible answer: When I put a book in my bookbag, the book moves down into the bag, which is in the same direction as the force that I apply.*

Visual Literacy: Work and Energy Transformations

Have students study the image in **Figure 14** and compare the image of the drummer on the left to the one on the right. Then ask the following question to assess their understanding of the diagram.

Ask: What energy transformations occur as the drums are lifted? *Chemical energy stored in the muscles of the drummer transforms to the kinetic energy of the drums moving upward. When the drums stop moving at the top of their travel, they no longer have kinetic energy, but they do have greater gravitational potential energy due to their higher position. Chemical energy stored in the muscles of the drummer also transformed to this increased gravitational potential energy.*

Ask: Once the drums are lifted and the drummer is standing still holding the drums, is work being done? *No. Holding up the weight of the drums might feel like work to the drummer, but since he is not exerting a force that is moving anything, his actions do not fit the scientific definition of work.*

Doing Work

Remind students that work is only done when the distance an object moves is in the same direction as the force that is applied. Then have the class read the paragraphs. Ask the following questions to informally assess students' understanding of this concept.

Guiding Questions

AL What are two things work depends on?	*Work depends on force and distance.*
OL Do you do more work when you pick up a pencil or when you pick up a backpack? Explain.	*You do more work when you pick up a backpack because it is heavier than a pencil and requires more force to move.*
BL Are you doing work when you put a pencil on your desk? Why or why not? Are you doing work when the pencil rests on your desk? Why or why not?	*You are doing work when you put a pencil on a desk because the pencil moves in the direction of the force that you apply. You are not doing work when the pencil rests on the desk because you are no longer applying force to the pencil.*

Word Origin

work

Have students read the Greek origin of the word *work*.

Ask: How does the Greek origin of work relate to the everyday use of the word? *Work involves doing activities, such as trying a case, treating patients, completing reports, collecting garbage, and so on.*

Ask: How does the Greek origin of work relate to the scientific use of the word? *Work involves acting on an object and making something happen, which is an activity of a sort.*

Calculating Work

Remind students that work depends on that force that is applied to an object or particle and the distance it moves. Then have them read the paragraphs and study the equation to solve for work.

Differentiated Instruction

AL Working in the Kitchen Have students work in pairs. Ask them to find a recipe from a cookbook or on the Internet. Have them list different types of work that are as the recipe is prepared. For example, chopping vegetables separates the pieces and pushes them apa Have them annotate their recipe to show how it can be represented by the work equation.

BL Write a Report Have students research race cars at th school library or on the Internet. Have them write a sho report to explain the energy transformations that occur when a car is raced. For example, the chemical energy the fuel converts to thermal energy, which creates stea which creates kinetic energy.

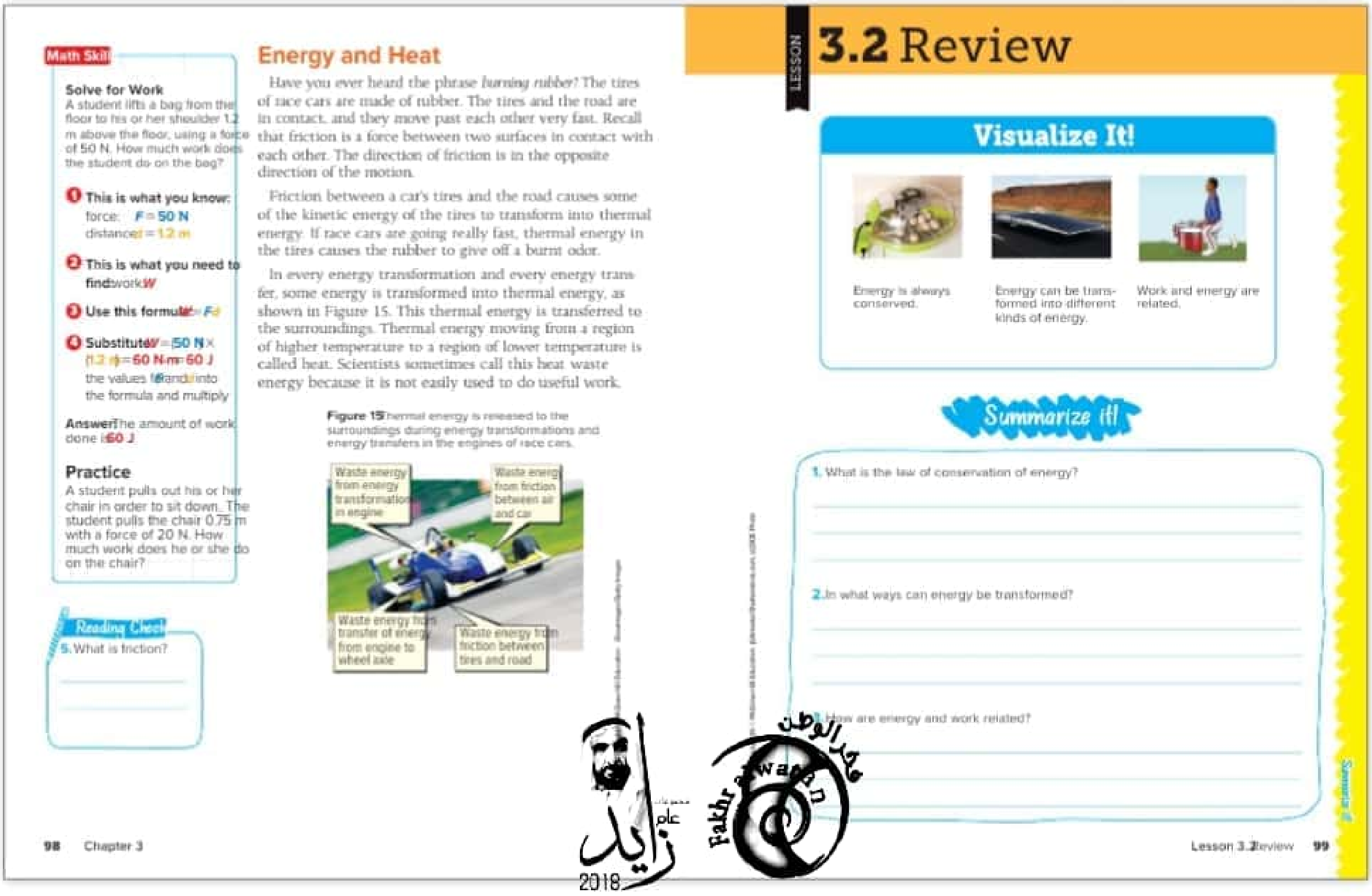
Teacher Toolbox

Reading Strategy

Active Reading Have each student write down three sentences in this lesson that they believe most clearly represent the main ideas. Read key sentences in the te and have students raise their hands if they have writte down the same sentence. Ask students to defend thei choices.

Math Skills

How much work has been done? Have students solve the following problem. A pair of students is preparing a presentation for the school. They have to move a lecte onto the stage of the auditorium. They push it 25.5 m f the wings of the stage, using a force of 150 N. How mu work have they done? *3,825 joules* Next, they hang a banner over the stage. They lift it 31 m and use a force 75 N. How much work have they done? *2,325 joules*


Math Skill

Solve for Work
A student lifts a bag from the floor to his or her shoulder 1.2 m above the floor, using a force of 50 N. How much work does the student do on the bag?

1. **This is what you know:** force: F = 50 N; distance: d = 1.2 m
2. **This is what you need to find:** work: W
3. **Use this formula:** W = Fd
4. **Substitute:** the values for F and d into the formula and multiply. W = (50 N) × (1.2 m) = 60 N·m = 60 J

Answer: The amount of work done is 60 J.

Practice
A student pulls out his or her chair in order to sit down. The student pulls the chair 0.75 m with a force of 20 N. How much work does he or she do on the chair?

Reading Check
5. What is friction?

Energy and Heat

Have you ever heard the phrase *burning rubber?* The tires of race cars are made of rubber. The tires and the road are in contact, and they move past each other very fast. Recall that friction is a force between two surfaces in contact with each other. The direction of friction is in the opposite direction of the motion.

Friction between a car's tires and the road causes some of the kinetic energy of the tires to transform into thermal energy. If race cars are going really fast, thermal energy in the tires causes the rubber to give off a burnt odor.

In every energy transformation and every energy transfer, some energy is transformed into thermal energy, as shown in Figure 15. This thermal energy is transferred to the surroundings. Thermal energy moving from a region of higher temperature to a region of lower temperature is called heat. Scientists sometimes call this heat waste energy because it is not easily used to do useful work.

Figure 15 Thermal energy is released to the surroundings during energy transformations and energy transfers in the engines of race cars.

Waste energy from energy transformation in engine
Waste energy from friction between air and car
Waste energy from transfer of energy from engine to wheel axle
Waste energy from friction between tires and road

LESSON 3.2 Review

Visualize It!

Energy is always conserved.
Energy can be transformed into different kinds of energy.
Work and energy are related.

Summarize it!

1. What is the law of conservation of energy?
2. In what ways can energy be transformed?
3. How are energy and work related?

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Lesson 3.2 Review 99

Math Skill

Work Equation

On chart paper or the board, write the mathematical symbols and units for force (*F, newtons*), distance (*d, meters*), and work (*W, joules*). Explain that a joule equals the amount of energy used by a force measuring one newton to move an object one meter. Then have students read the Math Skills box. Go through the sample equation with them step by step to help them understand how to solve for work when the amounts for the force and distance are known.

Practice

Have students solve the practice question. Then ask a volunteer to write the steps he or she used to find the answer on chart paper or the board.

$W = (20\ \text{N}) \times (0.75\ \text{m}) = 15\ \text{J}$

Energy and Heat

Ask students to rub their hands together rapidly and describe the heat sensation that they feel in their palms. Explain that the kinetic energy created friction that transformed into thermal energy that generated heat. Then have students read the paragraph and study the image **Figure 15.**

Guiding Questions

OL What is friction?	*Friction is a force that acts against the motion of two objects in contact with each other as they slide past each other.*
OL When is heat generated?	*Heat is generated when themal energy moves from a region of higher temperature to a region of lower temperature.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. Ask: **Which Key Concept does each image relate to?**

Summarize it!

Energy Transformations

Use Vocabulary

1. A(n)______ occurs when energy is converted from one form to another.

Understand Key Concepts

2. **Distinguish** between work and energy.

3. **Define** the law of conservation of energy in your own words.

4. Which is NOT an example of work?
   A. holding books in your arms
   B. lifting a box from a table
   C. placing a bowl on a high shelf
   D. pushing a cart across the room

5. **Describe** the energy transformations that occur when a piece of wood is burned.

Interpret Graphics

6. **Explain** the gravitational potential energy transformations that occur when the object at right is in motion.

7. **Summarize** Copy and fill in the graphic organizer below to show what work is the product of.

Critical Thinking

8. **Consider** Which energy transformations and energy transfers occur in a flashlight?

9. **Model** Draw a picture showing how energy is transferred to a sidewalk on a hot summer day. Label the different forms of energy in your drawing.

Math Skills

10. **Calculate** the work done by a bird pulling a worm from the dirt with a force of 0.05 N a distance 0.07 m.

My Notes

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Use Vocabulary

1. energy transformation

Understand Key Concepts

2. Work is the transfer of energy that occurs when a force makes an object or a particle move. Energy is the ability to cause change.
3. The law of conservation of energy says that energy can be transformed from one form to another but it can never be created or destroyed.
4. A holding books in your arms
5. Chemical energy stored in the bonds between the atoms in the molecules of the wood is transformed to thermal energy and light energy.

Interpret Graphics

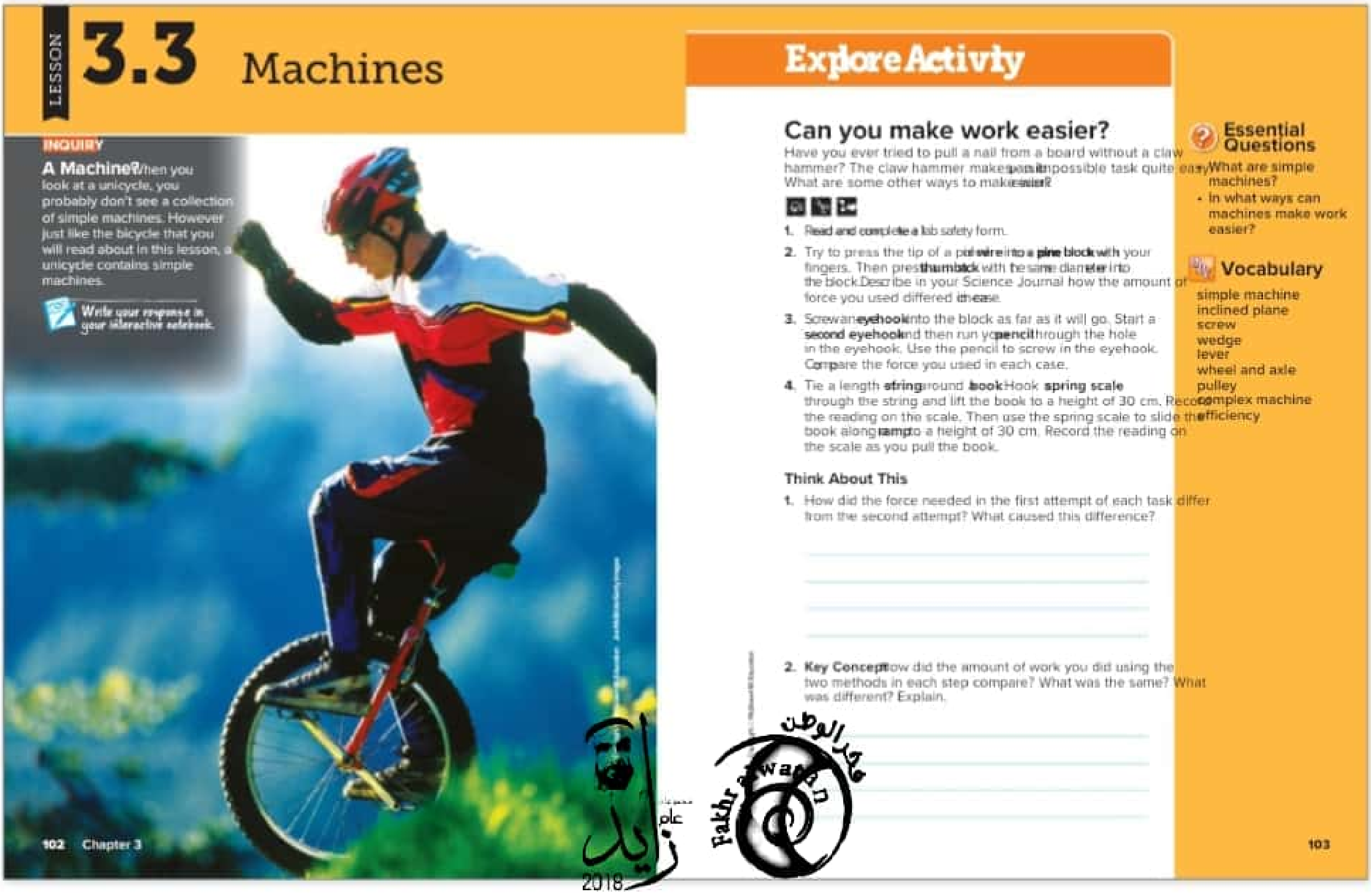
6. Sample answer: A car at the bottom of the wheel has the least gravitational potential energy. As it rises, its gravitational potential energy increases. At the top of the wheel, gravitational potential energy is at maximum. It begins to decrease as the car goes from the top of the wheel to the bottom.
7. force, distance (in any order)

Critical Thinking

8. Chemical energy in batteries is converted to electric energy, which is transferred to the bulb. The bulb transforms electric energy to radiant energy in the form of light waves and waste thermal energy which transfers radiant energy away from the flashlight.
9. Students should show radiant energy from the Sun in waves moving toward the sidewalk, and label thermal energy coming from the sidewalk.

Math Skills

10. 0.004 J



LESSON 3.3 Machines

INQUIRY

A Machine? When you look at a unicycle, you probably don't see a collection of simple machines. However just like the bicycle that you will read about in this lesson, a unicycle contains simple machines.

Write your response in your interactive notebook.

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Explore Activity

Can you make work easier?

Have you ever tried to pull a nail from a board without a claw hammer? The claw hammer makes an impossible task quite easy. What are some other ways to make work easier?

1. Read and complete a lab safety form.
2. Try to press the tip of a pol wire into a pine block with your fingers. Then press a thumbtack with the same diameter into the block. Describe in your Science Journal how the amount of force you used differed in each case.
3. Screw an eyehook into the block as far as it will go. Start a second eyehook and then run your pencil through the hole in the eyehook. Use the pencil to screw in the eyehook. Compare the force you used in each case.
4. Tie a length of string around a book. Hook a spring scale through the string and lift the book to a height of 30 cm. Record the reading on the scale. Then use the spring scale to slide the book along a ramp to a height of 30 cm. Record the reading on the scale as you pull the book.

Think About This

1. How did the force needed in the first attempt of each task differ from the second attempt? What caused this difference?
2. **Key Concept** How did the amount of work you did using the two methods in each step compare? What was the same? What was different? Explain.

Essential Questions

- What are simple machines?
- In what ways can machines make work easier?

Vocabulary

simple machine
inclined plane
screw
wedge
lever
wheel and axle
pulley
complex machine
efficiency

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INQUIRY

About the Photo **A Machine?** Discuss unicycles with students. Explain that this rider must stay balanced as he pushes the pedals to ride forward or backward. Have students identify some of the parts of the unicycle, such as the wheel, the pedals, the seat, the gears, the chain, and so on.

Guiding Questions

AL What does the word *machine* mean to you?	*Students may describe a machine as something that has many different parts and that can accomplish a task, such as washing clothes.*
OL What is one example of a machine?	*Students may describe different types of machines, such as cars, computers, or air conditioners.*
BL Do you think a unicycle is an example of a machine? Why or why not?	*Sample answer: Yes; it has several different parts, and a person can use it to move.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

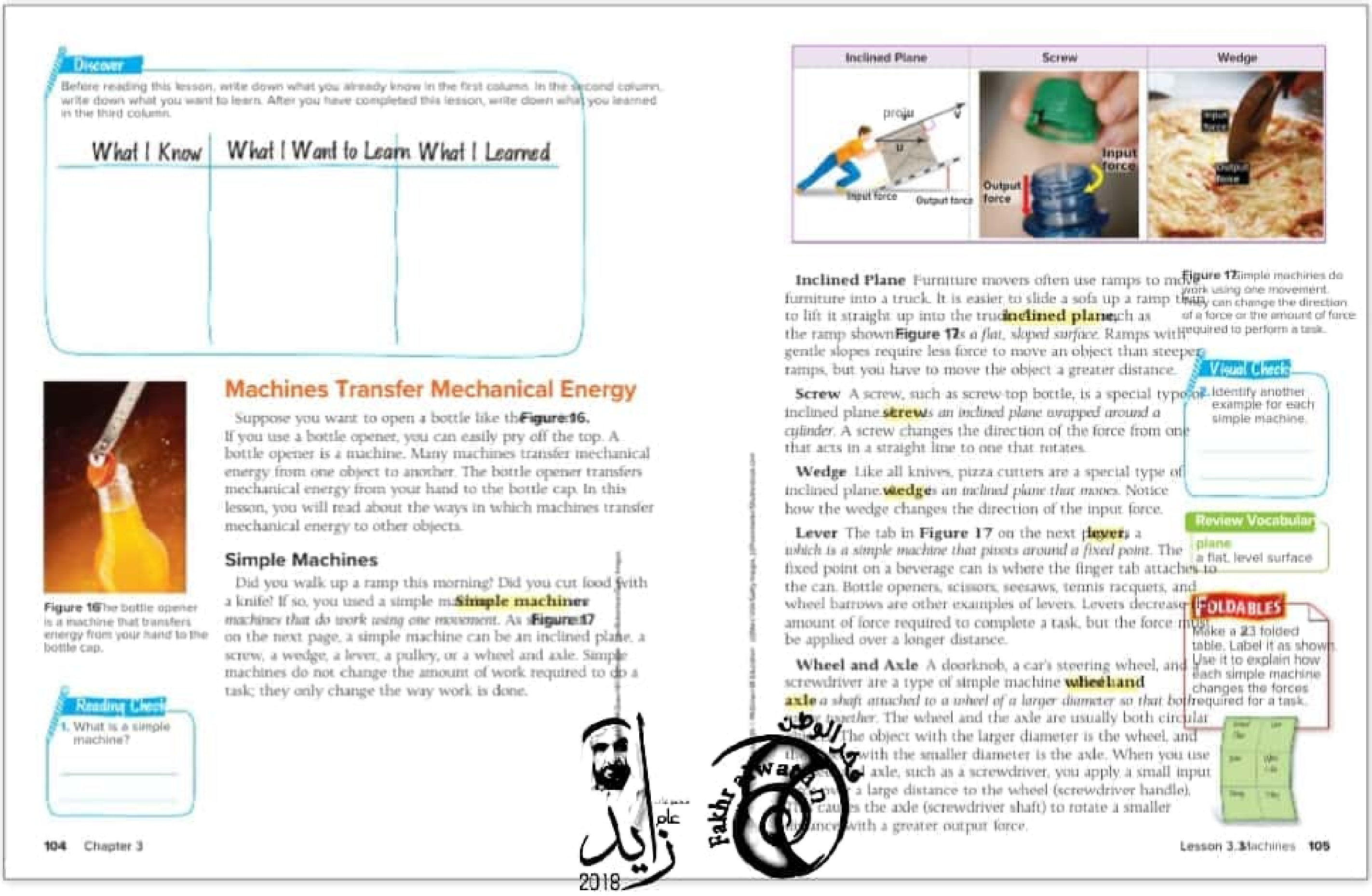
Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Predict the Definitions

1. Ask students to name some of the machines they use every day. Help them by pointing out items throughout the classroom. *bicycle, computer, stapler, doorstop, doorknob, telephone, string to open blinds*
2. Have them consider what makes something a machine.
3. Write the terms *simple machine* and *complex machine* on chart paper or on the board. Have students classify their examples of each.



Machines Transfer Mechanical Energy

Suppose you want to open a bottle like the Figure 16. If you use a bottle opener, you can easily pry off the top. A bottle opener is a machine. Many machines transfer mechanical energy from one object to another. The bottle opener transfers mechanical energy from your hand to the bottle cap. In this lesson, you will read about the ways in which machines transfer mechanical energy to other objects.

Figure 16 The bottle opener is a machine that transfers energy from your hand to the bottle cap.

Simple Machines

Did you walk up a ramp this morning? Did you cut food with a knife? If so, you used a simple ma **Simple machines** *machines that do work using one movement.* As Figure 17 on the next page, a simple machine can be an inclined plane, a screw, a wedge, a lever, a pulley, or a wheel and axle. Simple machines do not change the amount of work required to do a task; they only change the way work is done.

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Inclined Plane Furniture movers often use ramps to move furniture into a truck. It is easier to slide a sofa up a ramp than to lift it straight up into the truc **inclined plane**, ch as the ramp shown Figure 17 is *a flat, sloped surface.* Ramps with gentle slopes require less force to move an object than steeper ramps, but you have to move the object a greater distance.

Screw A screw, such as screw-top bottle, is a special type of inclined plane. **screw** is *an inclined plane wrapped around a cylinder.* A screw changes the direction of the force from one that acts in a straight line to one that rotates.

Wedge Like all knives, pizza cutters are a special type of inclined plane. **wedge** is *an inclined plane that moves.* Notice how the wedge changes the direction of the input force.

Lever The tab in **Figure 17** on the next p **lever**, a *which is a simple machine that pivots around a fixed point.* The fixed point on a beverage can is where the finger tab attaches to the can. Bottle openers, scissors, seesaws, tennis racquets, and wheel barrows are other examples of levers. Levers decrease the amount of force required to complete a task, but the force must be applied over a longer distance.

Wheel and Axle A doorknob, a car's steering wheel, and screwdriver are a type of simple machine **wheel and axle** *a shaft attached to a wheel of a larger diameter so that both rotate together.* The wheel and the axle are usually both circular. The object with the larger diameter is the wheel, and the with the smaller diameter is the axle. When you use a wheel and axle, such as a screwdriver, you apply a small input force a large distance to the wheel (screwdriver handle). This causes the axle (screwdriver shaft) to rotate a smaller distance with a greater output force.

Figure 17 Simple machines do work using one movement. They can change the direction of a force or the amount of force required to perform a task.

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Machines Transfer Mechanical Energy

Have students study Figure 16 and read the paragraph.

Simple Machines

Ask students to name some common tools and explain that the tools are examples of simple machines. Then ask students the following questions.

Guiding Questions

OL	Name one example of a simple machine.	*Sample answers: an inclined plane, a screw, a wedge, a lever, a pulley, a wheel and axle*
OL	What is a simple machine?	*Simple machines do work using one movement.*
BL	Why is a bottle opener an example of a simple machine?	*You only use one movement to do work with a bottle opener. You use it to lift up and remove a cap from a bottle.*

Inclined Plane / Screw / Wedge

Have students examine the images of the inclined plane, the screw, and the wedge from Figure 17. Use the following questions to informally assess students' understanding of the content.

Guiding Questions

AL	What are some other examples of an inclined plane?	*Sample answers include any sort of ramp including the wheelchair ramps next to stairs, ramps in garages, and a slide at a park.*
OL	Is the eyehook used in the Launch Lab an example of an inclined plane, a screw, or a wedge?	*It is an example of a screw because you twist it around to screw it into a piece of wood.*
BL	Using the arrows on the board, can you explain how a knife is an example of a wedge?	*When you cut food with a knife, you are pushing parts of the food apart. When you do that you apply a downward force that creates two output forces sideways.*

Review Vocabulary

plane

Have students read the definition of *plane*. Ask them to name examples of flat, level surfaces. *Sample answers: a table, a desk, a countertop, a mantel, and so on.* Discuss the definition of *incline*. Link the distinct definitions of the two words to the words *flat* and *sloped* in the definition of *inclined plane*.

Lever / Wheel and Axle

Have students examine the lever in Figure 17 and describe what this simple machine is doing. *It is applying a force to the top of the can and opening it.* Then have students read the paragraph and

Key Concept Check
3. What are examples of simple machines?

Reading Check
4. How is a complex machine different from a simple machine?

Pulley Have you ever raised a flag on a flagpole or watched someone raise a flag? The rope that you pull goes through a **pulley**, *which is a grooved wheel with a rope or cable wrapped around it.* A single pulley, such as the kind on a flagpole, changes the direction of a force. A series of pulleys decreases the force you need to lift an object because the number of ropes or cables supporting the object increases.

Complex Machines

Bicycles, such as the one in **Figure 18**, are made up of many different simple machines. The pedal stem is a lever. The pedal and gears together act as a wheel and axle. The chain around the gear acts as a pulley system. *Two or more simple machines working together are* **complex machines**. Complex machines, such as bicycles, use more than one motion to accomplish tasks.

Figure 18 A bicycle is a complex machine that is made of many simple machines.

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Machines and Work

Think of a window washer like the one in **Figure 19** on the next page. It takes a great amount of work to lift the washer's own weight plus the weight of buckets of water, window-washing tools, and the platform up in the air. The window washer is able to do this work because the pulley system that lifts him makes the work easier. Because two ropes are supporting the platform, the force required is half.

The work you do on a machine is called the input work. The work the machine does on an object is the output work. Recall that work is the product of force and distance. Machines make work easier by changing the distance the object moves or the force required to do work on an object.

Changing Distance and Force

To pull himself toward the top of the building, the window washer pulls down on a rope. The rope runs through a pulley system. The distance the window washer must pull the rope (the input distance) is much greater than the distance he moves (the output distance).

The force the window washer has to use to lift the platform (the input force) is much less than the force the pulley exerts on the platform (the output force). When the input distance of a machine is larger than the output distance, the output force is larger than the input force. This is true for all simple machines. Like other simple machines, the input force is decreased, but the distance it is applied is increased.

Changing Direction

Machines also can change the direction of a force. A window washer pulls down on the rope. The pulley system changes the direction of the force, which pulls the platform up.

Efficiency

Suppose the window washer wants to buy a new pulley system. One way to compare machines is to calculate each machine's efficiency. **Efficiency** *is the ratio of output work to input work.* In other words, it is a measure of how much work put into a machine is changed into useful output work. Input and output work are measured in joules (J). Efficiency is expressed as a percentage by multiplying the ratio by 100%.

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Complex Machines

Remind students about the examples of machines that they listed at the beginning of the lesson. Explain that most, if not all, of the machines they named are different from simple machines. They have many moving parts. Then have students read the paragraph and answer the following questions.

Guiding Questions

OL How is a complex machine different from a simple machine?	*A simple machine uses one motion to accomplish a task, and a complex machine uses several motions.*
BL Do you think scissors are an example of a complex machine? Why or why not?	*Yes; scissors are made of two or more simple machines working together. They include two levers and two wedges.*

Visual Literacy: A Complex Machine

Have students examine the diagram of a bike in **Figure 18.** Then ask the following questions to reinforce their understanding of both simple and complex machines.

Ask: **Why is a bicycle an example of a complex machine?** *It is made of two or more simple machines that work together.*

Machines and Work

Have students read the paragraphs and study **Figure 19.**

Ask: **Use the terms *input work* and *output work* to describe what happens when you hammer a nail.** *Sample answer: The input work is the work I do to move the hammer, and the output work the work the hammer does to drive the nail.*

Changing Distance and Force

Explain that some simple machines change direction and make work easier, but others change distance, such as an inclined plane. Have students read the paragraphs.

Changing Direction

Have students read the paragraph and then explain that a screw also changes the direction that a force is applied. Imagine trying to push a screw straight into a wall. However, if you rotate it, you change the direction. Now, the task is much easier and requires less force. Have students answer the following questions to assess their comprehension.

Guiding Questions

OL How does the pulley make raising the platform easier for the window washer?	*The window washer pulls the rope with less force but over a longer distance. This decreases the input force and changes the direction of the force.*
OL How can machines make work easier?	*Machines can make work easier by changing distance, increasing force, or changing the direction of a force.*
BL Is the machine used by the window washer most like an elevator or a ramp? Explain your answer.	*Both a ramp and an elevator could help lift the window washer and his materials. The pulley system the window washer is using is most like an elevator because the machine is lifting the object straight up, whereas an inclined plane does not.*

Efficiency

Explain that most household appliances have efficiency ratings. These ratings help consumers know how much energy the appliance will consume. Review the definition of *efficiency*. Then instruct students to read the paragraphs and study the equation.

Visual Literacy: Efficiency Equation

Instruct students to study the equation as you ask the following questions.

Newton's Laws and Simple Machines

Review Newton's three laws of motion: (1) an object at rest stays at rest unless unbalanced forces act on it; (2) the acceleration of an object increases as the force acting on it increases; (3) for every action force there is an equal but opposite reaction force. Write the three laws on chart paper or the board. Then have students read the section and answer the following questions.

Differentiated Instruction

AL What is Energy Star? Have students research the U.S. government's Energy Star program, which tracks the efficiency of everyday appliances. The government We[b site] is one place to begin. Ask students to research the program's goal, how it puts the efficiency equation into practice, and some ways it suggests increasing the en[ergy] efficiency of everyday items. Have students create a sh[ort] report on how the program works to conserve energy.

BL Design an Experiment Have students design an experiment to better understand how a simple machine makes work more efficient by changing force, distance [or] direction. Students should identify the simple machine, the materials needed, explain the hypothesis they are [going] to test, and describe all the steps of their experiment. T[he] report should include data on work and efficiency.

Teacher Toolbox

Reading Strategy

Main Idea and Supporting Details Have students reread the paragraphs on efficiency. Ask them to complete a "[main] idea and supporting details" chart to explain the mean[ing of] the term *efficiency*. Their charts should include a defin[ition] and supporting details, such as the efficiency equation.

Teacher Demo

Changing Distance or Direction? Display a complete doorknob assembly. Explain that it is a simple machine.

1. Ask students to predict if a doorknob changes dista[nce] or direction to make work easier.
2. Have students examine the doorknob, and ask them [to] identify the kind of simple machine it is. *a wheel and axle*
3. Remind students that a wheel has a larger diameter [than] an axle. **Ask: How do you think a wheel makes the work of the doorknob easier?** *When you turn a doorknob, the knob moves around a larger distance than the shaft. That makes it easier to unlatch the d[oor].* **Ask: Does a doorknob change distance or direction?** *It changes distance.*

Math Skills

Solving for Efficiency Have students calculate the efficiency of two machines:

1. A bicycle requires 200 J of input work but only 180 J [to] make the bicycle move. How efficient is it? $\left(\frac{180}{200} \times 100 = 90\%\right)$
2. A car requires 3,000 J of input work but only 1,000 J [to] make the car move. How efficient is it? $\left(\frac{1000}{3000} \times 100 = 33\%\right)$

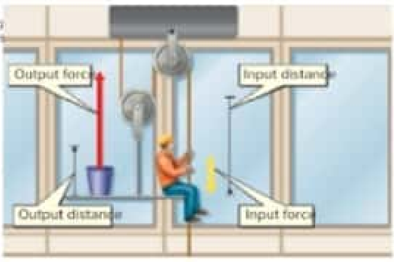

Figure 19 The window washer lifts his platform using a pulley system that increases the distance over which the force is exerted, decreases the input force needed, and changes the direction of the force.

Visual Check

5. How does the pulley make raising the platform easier for the window washer?

Key Concept Check

6. How can machines make work easier?

Word Origin

efficiency
from Latin *efficere*, means "work out, accomplish"

Efficiency Equation

$$\text{efficiency (in \%)} = \frac{\text{output work (in J)}}{\text{input work (in J)}} \times 100\% = \frac{W_{out}}{W_{in}} \times 100\%$$

The window washer considers two systems that require 100 J of input work. The first one does 90 J of output work on his platform. The other pulley system does 95 J of output work. The efficiency of the first pulley system is (90 J/100 J) × 100% = 90%. The efficiency of the second one is (95 J/100 J) × 100% = 95%. The window washer decides to buy the second pulley system.

The efficiency of a machine is never 100%. Some work is always transformed into wasted thermal energy because of friction. One way to improve the efficiency of a machine is to lubricate the moving parts by applying a substance, such as oil, to them. This reduces the friction between the moving parts so that less input work is transformed to waste energy.

My Notes

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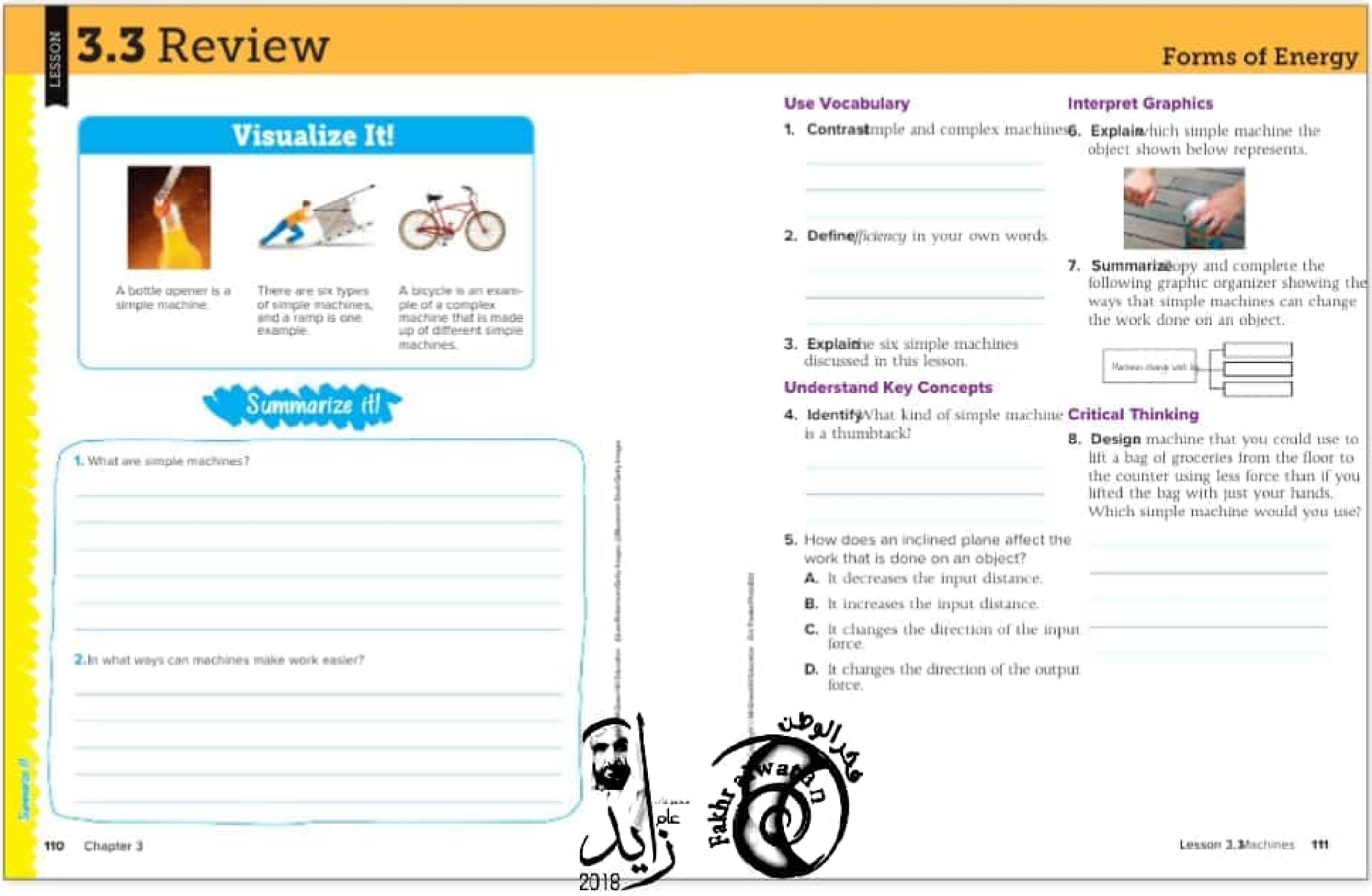
OL What is Newton's third law?	*If an object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.*
OL What does acceleration equal?	*Acceleration equals the force that's applied to an object divided by the mass of the object.*
OL How can simple machines demonstrate Newton's laws of motion?	*Sample answers: Newton's first law—A door held open by a door stop (inclined plane) stays open unless a force such as wind, moves it. Newton's second law— When you use a screwdriver as a lever to open a paint can, the lid accelerates in the direction the screwdriver applies the force (up). Newton's third law—When someone pushes down on a lever, such as a bicycle handbrake, the lever pushes back with equal and opposite force.*

Efficiency Equation

$$\text{efficiency (in \%)} = \frac{\text{output work (in J)}}{\text{input work (in J)}} \times 100\% = \frac{W_{out}}{W_{in}} \times 100\%$$

Ask: **How is efficiency expressed?** *Efficiency is expressed as a percentage.*

Ask: **How does the fraction shown in the equation relate to the definition of efficiency in the book?** *In an equation you express ratios as fractions. Fractions show the relationship between the two numbers they include. Efficiency is the ratio of output work to input work multiplied by 100 percent.*


LESSON 3.3 Review

Forms of Energy

Visualize It!

A bottle opener is a simple machine.

There are six types of simple machines, and a ramp is one example.

A bicycle is an example of a complex machine that is made up of different simple machines.

Summarize it!

1. What are simple machines?

2. In what ways can machines make work easier?

Use Vocabulary

1. Contrast simple and complex machines.

2. Define efficiency in your own words.

3. Explain the six simple machines discussed in this lesson.

Understand Key Concepts

4. Identify What kind of simple machine is a thumbtack?

5. How does an inclined plane affect the work that is done on an object?

A. It decreases the input distance.

B. It increases the input distance.

C. It changes the direction of the input force.

D. It changes the direction of the output force.

Interpret Graphics

6. Explain which simple machine the object shown below represents.

7. Summarize Copy and complete the following graphic organizer showing the ways that simple machines can change the work done on an object.

Critical Thinking

8. Design machine that you could use to lift a bag of groceries from the floor to the counter using less force than if you lifted the bag with just your hands. Which simple machine would you use?

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Lesson 3.3 Machines 111

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize it!

Use Vocabulary

1. Simple machines do work using one movement. Complex machines are made up of two or more simple machines. They use more than one motion to do work.

2. Sample answer: Efficiency is the ratio of output work to input work multiplied by 100 percent.

3. An inclined plane is a flat, sloped surface. A screw is an inclined planed wrapped around a cylinder. A wedge is an inclined plane that moves. Levers are simple machines that move around a fixed point. A shaft attached to a wheel of a larger diameter so that both rotate together is a wheel and axle. A pulley is a grooved wheel with a rope or cable wrapped around it.

Understand Key Concepts

4. a wedge

5. B. It increases the input distance.

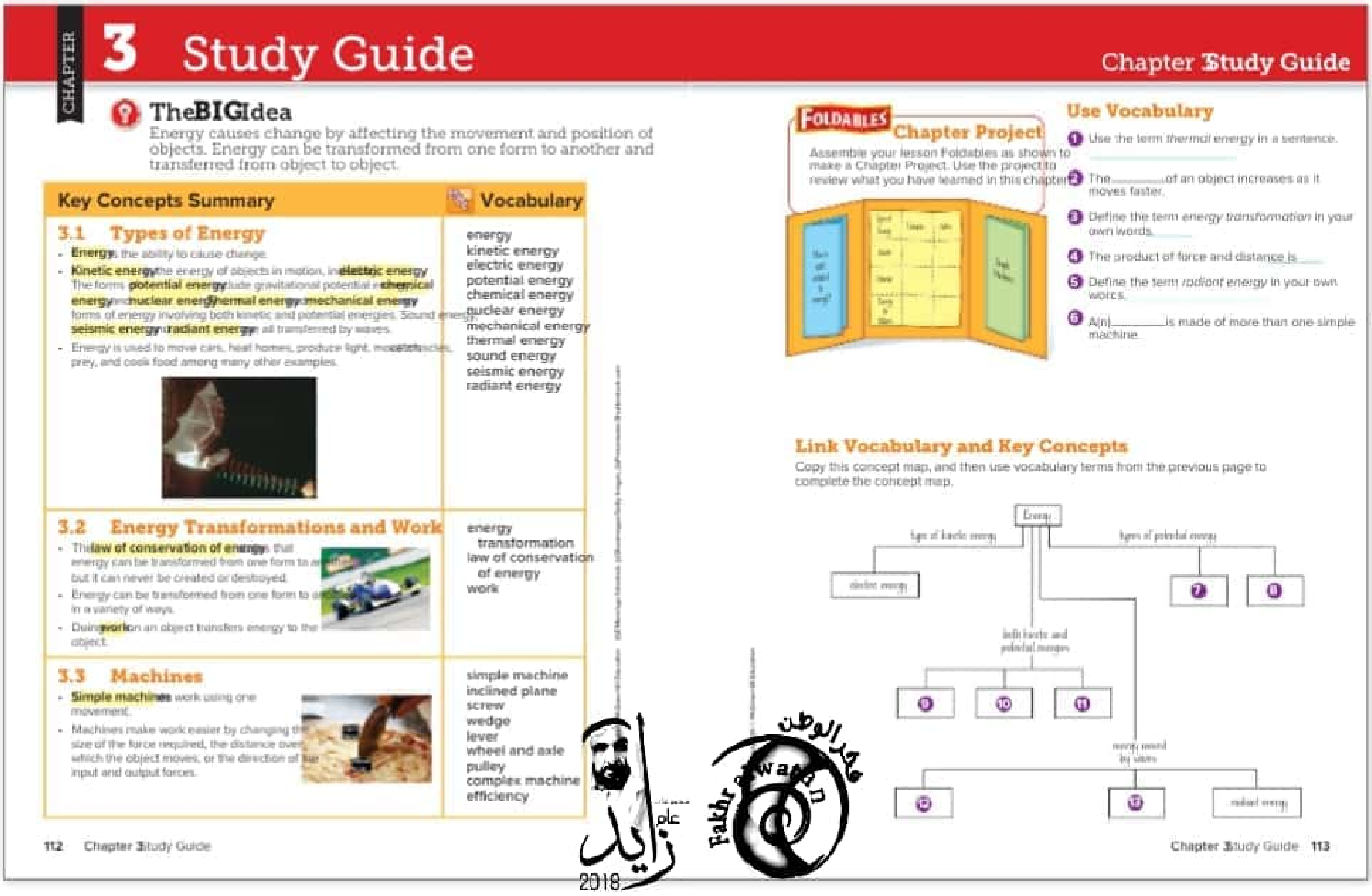
Interpret Graphics

6. a lever

7. changing the size of the force, changing the distance the force is applied, changing direction of the force (in any order)

Critical Thinking

8. Answers will vary. For example, students may use an inclined plane or a pulley as the simple machine.



Key Concepts Summary

Study Strategy: Match Pictures to Captions

Students sometimes remember what they have studied without developing a true understanding of the concepts. Use this activity to help students better understand what they have read in this chapter.

1. Ask students to rewrite the Key Concepts in their own words in their Science Journals.
2. Then ask them to locate photographs in magazines or newspapers or on the Internet that illustrate those ideas. For example, for the Key Concept that explains potential energy, they might clip a photo of a piece of coal or other fossil fuel.
3. After finding photos to match each concept, have students put them together on a poster, using their Key Concept sentences as captions for the different images.

Example:

Potential energy is energy that is stored.

Vocabulary

Vocabulary Quiz

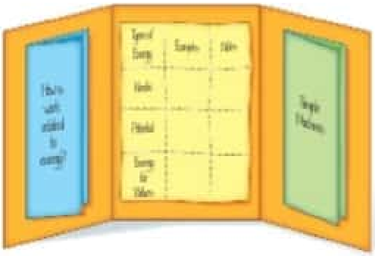
Have students work in pairs to review the vocabulary terms. This activity will help students review the terms and their meanings.

1. Working in pairs, have students write the vocabulary terms on separate index cards. Ask them to include a definition for each term on the back of the index card.
2. Have students take turns quizzing each other by reading out either a term or a definition. The student being quizzed should give the appropriate definition or term.
3. As a variation of this activity, students could identify an example of a term instead of a definition.

Front of card: *electric energy*

Back of card: *a form of kinetic energy that is carried by an electric current*

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Use Vocabulary

1. Answers will vary. Sample answer: A cup of hot tea contains more thermal energy than a cup of iced tea.
2. kinetic energy
3. Sample answer: An energy transformation occurs when energy is converted from one form to another.
4. work
5. Sample answer: Radiant energy is energy carried by electromagnetic waves, such as energy from the Sun.
6. complex machine

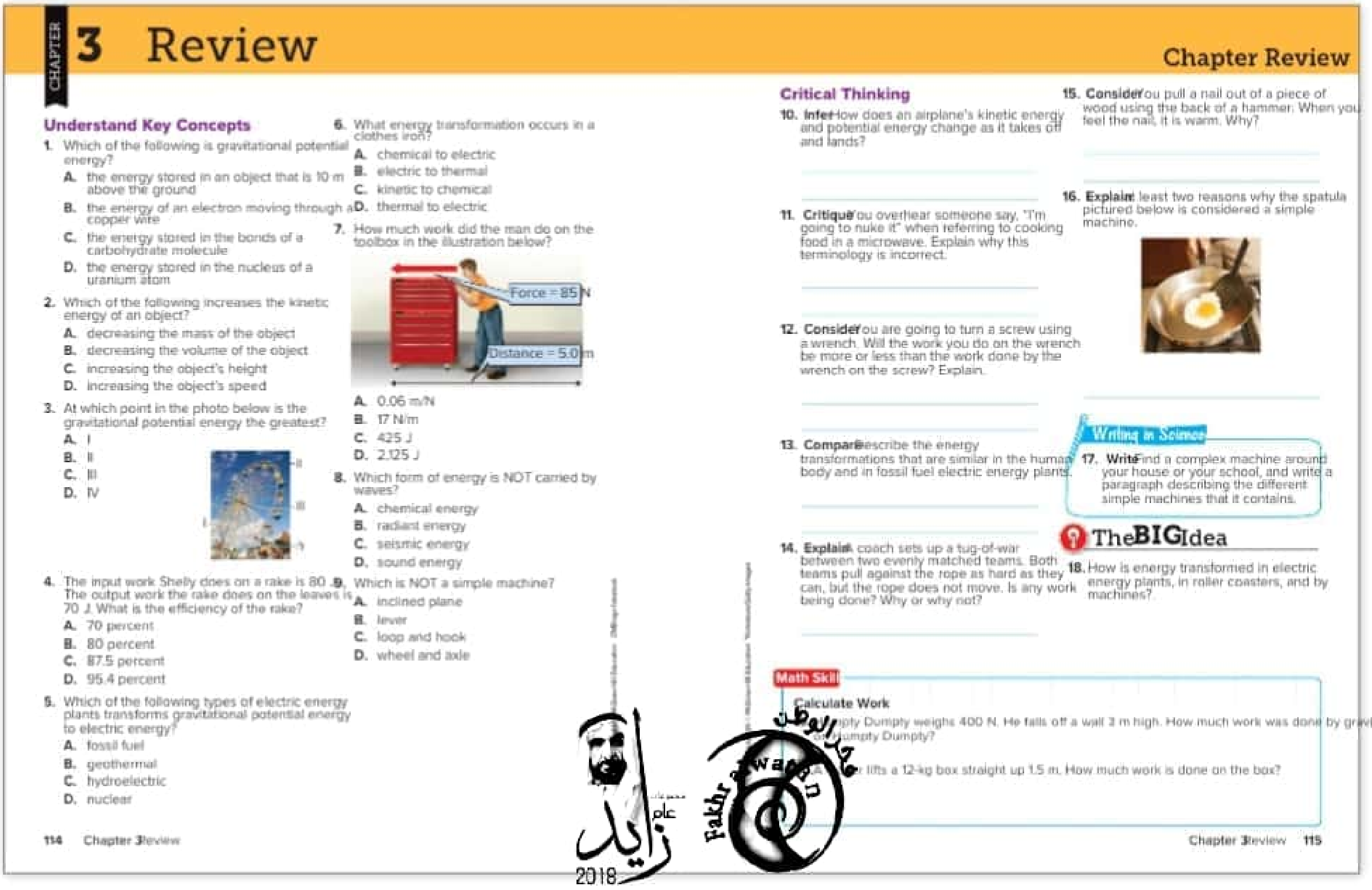
Link Vocabulary and Key Concepts

7–8. (in any order) chemical energy, nuclear energy

9–11. (in any order) mechanical energy, thermal energy, geothermal energy

12–13. (in any order) sound energy, seismic energy

Teacher Notes



CHAPTER 3 Review

Chapter Review

Understand Key Concepts

1. Which of the following is gravitational potential energy?
A. the energy stored in an object that is 10 m above the ground
B. the energy of an electron moving through a copper wire
C. the energy stored in the bonds of a carbohydrate molecule
D. the energy stored in the nucleus of a uranium atom

2. Which of the following increases the kinetic energy of an object?
A. decreasing the mass of the object
B. decreasing the volume of the object
C. increasing the object's height
D. increasing the object's speed

3. At which point in the photo below is the gravitational potential energy the greatest?
A. I
B. II
C. III
D. IV

4. The input work Shelly does on a rake is 80 J. The output work the rake does on the leaves is 70 J. What is the efficiency of the rake?
A. 70 percent
B. 80 percent
C. 87.5 percent
D. 95.4 percent

5. Which of the following types of electric energy plants transforms gravitational potential energy to electric energy?
A. fossil fuel
B. geothermal
C. hydroelectric
D. nuclear

6. What energy transformation occurs in a clothes iron?
A. chemical to electric
B. electric to thermal
C. kinetic to chemical
D. thermal to electric

7. How much work did the man do on the toolbox in the illustration below?

A. 0.06 m/N
B. 17 N/m
C. 425 J
D. 2,125 J

8. Which form of energy is NOT carried by waves?
A. chemical energy
B. radiant energy
C. seismic energy
D. sound energy

9. Which is NOT a simple machine?
A. inclined plane
B. lever
C. loop and hook
D. wheel and axle

Critical Thinking

10. Infer How does an airplane's kinetic energy and potential energy change as it takes off and lands?

11. Critique You overhear someone say, "I'm going to nuke it" when referring to cooking food in a microwave. Explain why this terminology is incorrect.

12. Consider You are going to turn a screw using a wrench. Will the work you do on the wrench be more or less than the work done by the wrench on the screw? Explain.

13. Compare Describe the energy transformations that are similar in the human body and in fossil fuel electric energy plants.

14. Explain A coach sets up a tug-of-war between two evenly matched teams. Both teams pull against the rope as hard as they can, but the rope does not move. Is any work being done? Why or why not?

15. Consider You pull a nail out of a piece of wood using the back of a hammer. When you feel the nail, it is warm. Why?

16. Explain at least two reasons why the spatula pictured below is considered a simple machine.

Writing in Science

17. Write Find a complex machine around your house or your school, and write a paragraph describing the different simple machines that it contains.

The BIG Idea

18. How is energy transformed in electric energy plants, in roller coasters, and by machines?

Math Skill

Calculate Work

Humpty Dumpty weighs 400 N. He falls off a wall 3 m high. How much work was done by gravity on Humpty Dumpty?

... lifts a 12-kg box straight up 1.5 m. How much work is done on the box?

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Chapter 3 Review 115

Understand Key Concepts

1. **A.** the energy stored in an object that is 10 m above the ground
2. **D.** increasing the object's speed
3. **B.** II.
4. **C.** 87.5 percent
5. **C.** hydroelectric
6. **B.** electric to thermal
7. **C.** 425 J
8. **A.** chemical energy
9. **C.** loop and hook

Critical Thinking

10. As an airplane takes off, its kinetic energy increases because it is moving faster and faster. Its gravitational potential energy also increases as it moves farther from Earth's surface. Its kinetic energy decreases as its speed decreases; its gravitational potential energy decreases as its height above Earth decreases.

11. When someone says they are going to "nuke" it, they infer that they are using nuclear energy to cook the food. Actually, the person is using radiant energy in the form of microwaves to cook the food

12. Work you do on the wrench will be more than the work done by the wrench. Because of the law of conservation of energy, the wrench cannot do more work than you or it would be creating energy.

13. Both fossil fuel electric energy plants and the human body convert chemical energy stored in plants to energy that is used to perform specific tasks.

14. No work is being done, because there is no movement.

15. In every energy transfer, some energy is converted to thermal energy in the surrounding materials. There is a lot of friction between the nail and the wood, so a lot of thermal energy is transferred to the nail during the energy transfer.

16. The part that is moving the egg has an inclined plane surface so that it can slip under the food easier. When you flip the egg over, you use the spatula as a lever.

Writing in Science

17 Answers will vary. Many good topic choices for the paragraph exist in the kitchen and bathroom. A can opener involves wedges and wheels and axles on the gears, a wedge on the blade, and a lever on the handles. Similarly a nail clipper is a wedge and a lever. A pizza cutter is a wedge.

The BIG Idea

18 Energy is transformed from one form to another in electric energy plants. For example, in nuclear energy plants, the potential energy stored in the nucleus of an atom is transformed into electric energy in the nuclear reactor. In roller coasters, gravitational potential energy is transformed into kinetic energy as the height above Earth changes in the roller coaster and as its speed changes. Machines change the direction of the force, the distance it is applied, and the size of the force required to do work.

19 The pulleys allow the sailors to pull down on the ropes to lift the sails instead of climbing the poles to pull the sails into place.

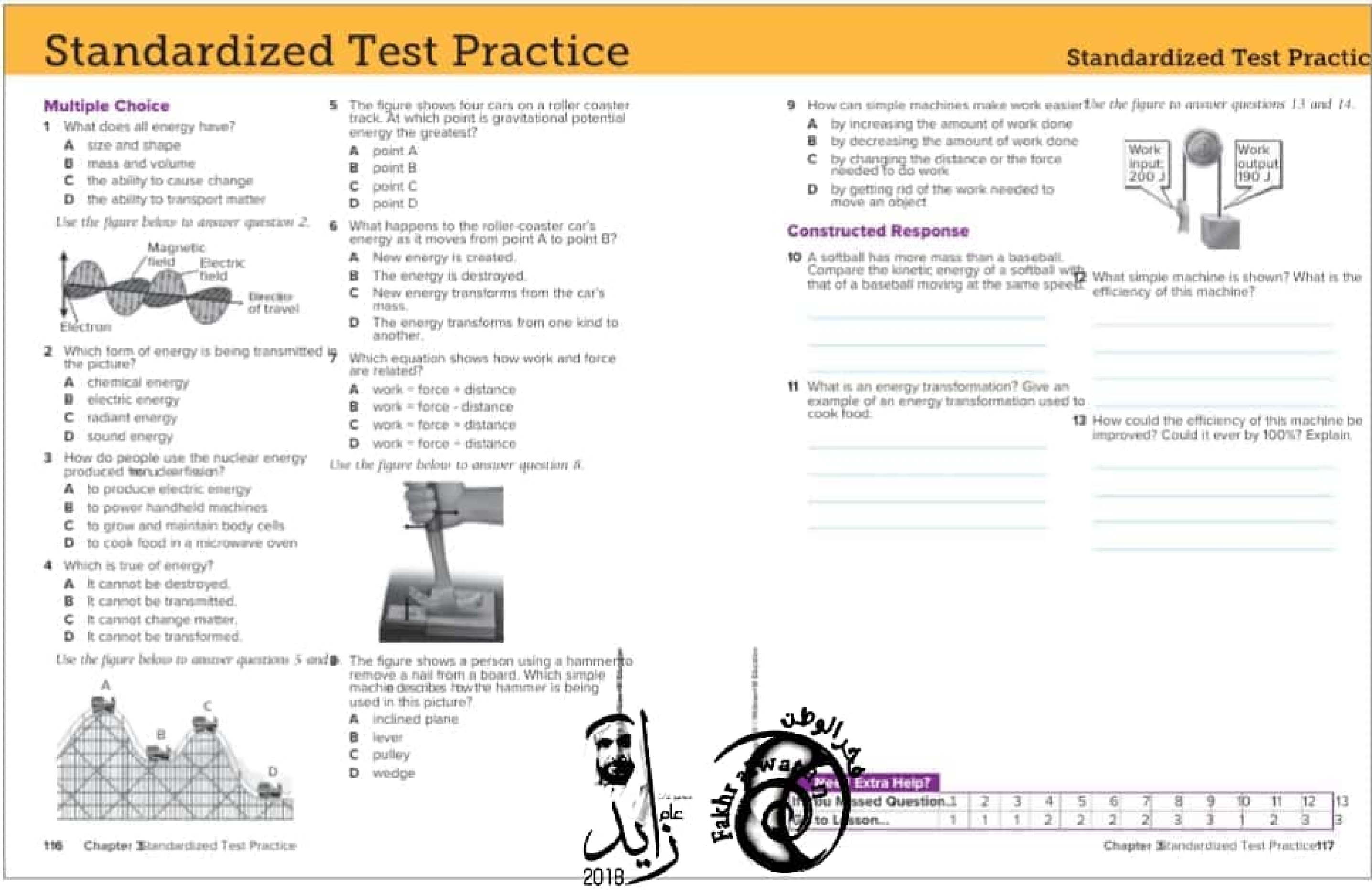
Math Skill

Calculate Work

20 $W = 400\ N \times 3\ m = 1200\ J$

21 $W = (9.8\ m/s^2 \times 12\ kg) \times 1.5\ m = 176.4\ J$

Teacher Notes



Standardized Test Practice

Multiple Choice

1 What does all energy have?
- A size and shape
- B mass and volume
- C the ability to cause change
- D the ability to transport matter

Use the figure below to answer question 2.

2 Which form of energy is being transmitted in the picture?
- A chemical energy
- B electric energy
- C radiant energy
- D sound energy

3 How do people use the nuclear energy produced from nuclear fission?
- A to produce electric energy
- B to power handheld machines
- C to grow and maintain body cells
- D to cook food in a microwave oven

4 Which is true of energy?
- A It cannot be destroyed.
- B It cannot be transmitted.
- C It cannot change matter.
- D It cannot be transformed.

Use the figure below to answer questions 5 and 6.

5 The figure shows four cars on a roller coaster track. At which point is gravitational potential energy the greatest?
- A point A
- B point B
- C point C
- D point D

6 What happens to the roller-coaster car's energy as it moves from point A to point B?
- A New energy is created.
- B The energy is destroyed.
- C New energy transforms from the car's mass.
- D The energy transforms from one kind to another.

7 Which equation shows how work and force are related?
- A work = force + distance
- B work = force - distance
- C work = force × distance
- D work = force ÷ distance

Use the figure below to answer question 8.

8 The figure shows a person using a hammer to remove a nail from a board. Which simple machine describes how the hammer is being used in this picture?
- A inclined plane
- B lever
- C pulley
- D wedge

9 How can simple machines make work easier?
- A by increasing the amount of work done
- B by decreasing the amount of work done
- C by changing the distance or the force needed to do work
- D by getting rid of the work needed to move an object

Constructed Response

10 A softball has more mass than a baseball. Compare the kinetic energy of a softball with that of a baseball moving at the same speed.

11 What is an energy transformation? Give an example of an energy transformation used to cook food.

Use the figure to answer questions 12 and 13.

12 What simple machine is shown? What is the efficiency of this machine?

13 How could the efficiency of this machine be improved? Could it ever be 100%? Explain.

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13
Go to Lesson...	1	1	1	2	2	2	2	3	3	1	2	3	3

Multiple Choice

1 **C—Correct.** A, B, and D are not true of all forms of energy.

2 **C—Correct.** A is incorrect because the dark- and light-shaded fields are perpendicular to each other. B is incorrect because the electron vibration produces the light-shaded field in one plane. D is incorrect because both fields carry the energy of an electromagnetic wave.

3 **A—Correct.** B is true of electric and chemical energy, C is true of chemical energy, and D is true of radiant energy.

4 **A—Correct.** B, C, and D are incorrect because the opposite of each statement is true.

5 **A—Correct.** B, C, and D are incorrect because they are all at lower heights than point A.

6 **D—Correct.** A and B are incorrect because of the law of conservation of energy, and C is incorrect because a roller coaster car's energy is not explained by conversions between matter and energy.

7 **C—Correct.** A, B, and D do not show that work is the product of force and distance.

8 **B—Correct.** A and D can be true of a hammer but not as it is shown here, and C is incorrect because a hammer does not have a rope wrapped around a grooved wheel.

9 **C—Correct.** A and B are incorrect because machines do not increase or decrease the amount of work done. D is incorrect because a machine cannot eliminate work output.

Constructed Response

10 If the two balls are traveling at the same speed, the kinetic energy depends on mass. The softball would have more kinetic energy than the baseball.

11 Sample answer: An energy transformation occurs when energy is converted from one form to another. On a gas stove, for example, the chemical energy of gas is converted to thermal energy when the gas is burned. This thermal energy is transferred to the food. As its temperature increases, the food cooks.

12 The pulley's efficiency is 95 percent.

13 The efficiency of the pulley system could be increased by reducing friction at the center of the pulley. Also, reducing any slippage of the line that runs through the pulley would result in less wasted thermal energy produced due to friction between the line and the pulley. The efficiency of this machine can never be 100%. Friction never can be totally eliminated in any machine.

Answer Key

Question	Answer
1	C
2	C
3	A
4	A
5	A
6	D
7	C
8	B
9	C
10	See extended answer.
11	See extended answer.
12	See extended answer.
13	See extended answer.

CHAPTER 4

Matter and Atoms

TheBIGIdea
How does the classification of matter depend on atoms?

LESSON **4.1 Substances and Mixtures**

- What is the relationship among atoms, elements, and compounds?
- How are some mixtures different from solutions?
- How do mixtures and compounds differ?

LESSON **4.2 The Structure of Atoms**

- Where are protons, neutrons, and electrons located in an atom?
- How is the atomic number related to the number of protons in an atom?
- What effect does changing the number of particles in an atom have on the atom's identity?

PAGE KEELEY SCIENCE PROBES

Describing Atoms

Five friends were talking about the differences among solid, liquids, and gases. They each agreed that the differences have to do with the particles in each type of matter. However, they disagreed about which differences determine whether the matter is a solid, liquid, or gas. This is what they said:

Hessa: I think it has to do with the number of particles.

Humaid: I think it has to do with the shape of the particles.

Halima: I think it has to do with the size of the particles.

Sumayya: I think it has to do with the movement of the particles.

Mazen: I think it has to do with how hard or soft the particles are.

With whom do you agree most? ________________ Explain why you agree with that friend.

Matter and Atoms

TheBIGIdea

There are no right or wrong answers to these questions. Write studentgenerated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL Why does it mean to classify?	*Classify means to organize or group things in a meaningful way.*
OL Why is it important to classify matter?	*The classification of matter helps us to study it in an organized way so that we can understand the similarities and differences between substances.*
BL How might studying atoms help scientists classify matter?	*An atom is the smallest particle of an element that retains the properties of that element. Studying the atom might help scientists learn more about the elements, how they are different and how they are the same, and how they can be classified or combined.*

Describing Atoms

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the

Get Ready to Read

What do you think?
Use this anticipation guide to gauge students' background knowledge and preconceptions about matter and atoms. At the end of the chapter, ask students to read and evaluate their earlier responses. Students should feel comfortable changing any of their responses.

Anticipation Set for Lesson 1

1. Things that have no mass are not matter

Agree. Matter is anything that takes up space and has mass.

2. The arrangement of particles is the same throughout a mixture.

Disagree. The arrangement of particles is the same throughout some mixtures, but the arrangement is not the same throughout all mixtures.

Science Content Background

Lesson 1

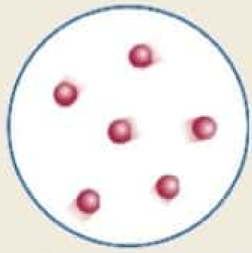
Substances and Mixtures

Atoms, Elements, and Compounds Matter is anything that has mass and takes up space. Examples of matter include: the ground below us, the air we breathe, and many other different kinds of materials. All matter is made of parts that are too small to be seen without a powerful microscope. These include atoms, which are the fundamental particles or building blocks of all of matter. All the objects that exist in the world are made of atoms. Some substances are elements and contain only one kind of atom. Others are compounds that made of a combination of two or more kinds of atoms that have chemically bonded together. Sodium (Na) is an element, while salt (NaCl) is a compound of sodium and chlorine. While the number of elements is limited—about 115 have currently been discovered—there are literally millions of compounds because of the various ways that the different kinds of atoms can come together.

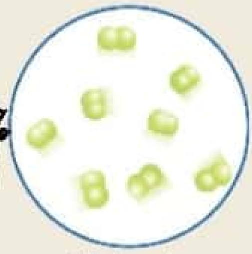
Mixtures vs. Solutions Materials can be combined to make something new. Most of the materials that we see or use each day are composed of a combination of substances. There are millions of different combinations. Some of them include atoms that bond, while others don't. When two or more substances combine but do not physically bond, they form a mixture.

There are many more mixtures than there are pure elements and compounds. Mixtures have unique properties from the components they are made from and some mixtures have different properties at different compositions. Homogeneous mixtures contain substances that are evenly mixed, while heterogeneous mixtures contain substances that are not. Examples of heterogeneous mixtures include fruit salad, concrete, oil and vinegar, and blood. Soda, fruit gelatins, and salt water are examples of homogeneous mixtures. Solution is another word for a homogeneous mixture, which forms when one substance dissolves into another.

Mixtures v. Compounds Many kinds of combinations can be made from even a small number of substances. Some combinations are compounds while others are mixtures. It is difficult to determine the difference between a homogeneous mixture and a compound when you study them with the naked eye because homogeneous mixtures are evenly mixed. However, unlike compounds, homogeneous mixtures do not bond at the atomic level and they can be separated using physical means, such as evaporation.



Individual atoms



Molecules

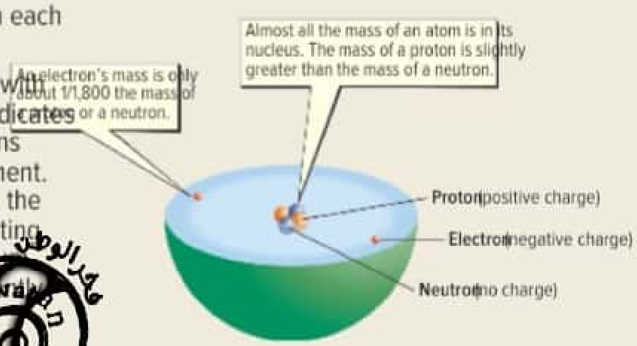
Lesson 2

The Structure of Atoms

Protons, Neutrons, and Electrons Atoms are made of tiny particles, called protons, neutrons, and electrons. All atoms are structured in the same way. The structure of an atom consists of a nucleus with electrons moving in empty space around it. The empty space is often described as a cloud because the exact position and speed of an electron cannot be determined at a given moment. The nucleus contains protons and neutrons held together by subatomic forces. The negatively charged electrons are attracted to the positively charged protons, which draws them to the nucleus. However, some electrons are closer to the nucleus than others. The distance between electrons and the nucleus is directly related to the amount of force the particles have on each other.

Atomic Number On the periodic table, each element is listed with an atomic number. This number defines the element and indicates the number of protons in the nucleus. The number of protons determines the physical and chemical properties of an element. Every element has a unique number of protons. As a result, the periodic table is arranged according to atomic number, starting with hydrogen (atomic number 1) and ending with ununoctium (atomic number 118), which is the temporary name of a recently discovered element.

An Atom's Identity The atoms of an element are not necessarily all the same. They can differ in a couple of ways. Although an atom cannot gain or lose protons without losing its identity, it can gain or lose electrons. A neutral, or uncharged, atom has the same number of electrons as protons. A charged atom has gained or lost electrons, becoming an ion. A positive ion has fewer electrons than protons, while a negative ion has more electrons than protons. Ions form different kinds of bonds compared to neutral atoms. Atoms can also have a different number of neutrons than protons and retain their identity. An isotope is one of two or more atoms with the same number of protons, but a different number of neutrons. Isotopes can be useful in different ways. For example, they can be studied to help date ancient rocks, artifacts, and other objects.



Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Materials may be composed of parts that are too small to be seen without magnification.

* All materials have certain physical properties, such as strength, hardness, flexibility, durability, resistance to water and fire, and ease of conducting heat.

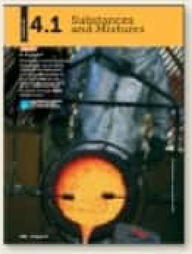
* A lot of different materials can be made from a small number of basic kinds of materials.

* When a new material is made by combining two or more materials, it has properties that are different from the original materials.

* Collections of pieces (powders, marbles, sugar cubes, or wooden blocks) may have properties that the individual pieces do not.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Substances and Mixtures



1. An atom is a building block of matter. An element is matter made of only [illegible] atom. A compound is a substance that contains [illegible]wo or more elements.

2. A heterogeneous mixture [illegible] a solution because the substances that make up a heterogeneous mixture are not evenly mixed. The substances that make up a solution, or a homogeneous mixture, are evenly mixed.

3. Mixtures differ from compounds in their composition, whether their parts join, and the properties of their parts.

Lesson 2 The Structure of Atoms

4. The center of an atom is the nucleus. The nucleus contains protons and neutrons. Electrons occupy the empty space in an atom outside the nucleus.

5. The identity of an atom is determined by its atomic number. The atomic number is the number of protons in the atom.

6. The identity of an atom stays the same if the number of neutrons or electrons changes.

Components of Mixtures Don't Mix

Find Out What Students Think

Students may think that...

... changing the amount of substances in a mixture fundamentally changes the mixture. For instance, they may believe that adding a little bit of sugar to a lot of water produces sweetened water, while adding a little bit of water to a lot of sugar produces sugary syrup, and that these two mixtures are unrelated.

Discussion

For most students, the idea of a mixture is not that difficult. The misconceptions arise due to differences that can occur when the components are mixed in various proportions. It is important that students understand that the same two substances can mix in different ways at different proportions, but still form the same kind of mixture. Changing the amount of one substance does not change the mixture's identity. **Ask:** When two substances are mixed together, do they lose their individual properties? **No, the substances retain their individual properties.** **Ask:** Do substances bond in a mixture and form something new? **No, they don't chemically bond the way elements in a compound do.** **Ask:** Since substances retain their properties and don't bond, does adding more or less of a substance change the identity of the mixture? **No**

Promote Understanding

Activity Provide groups of students with cornstarch, powdered drink mix, water, and beakers or plastic bowls that will allow easy mixing. Have students prepare the following mixtures:

- 5 mL drink mix in 25 mL water
- 30 mL cornstarch in 10 mL water (approximate)
- 25 mL drink mix in 5 mL water
- 10 mL drink mix in 10 mL cornstarch

The second mixture should form a colloid, which is a type of mixture in which one substance is evenly dispersed throughout another. The mixture appears to be homogeneous, but is actually heterogeneous because the substances do not dissolve. Milk is an example of a colloid. Have students describe the properties of each mixture compared to the properties of the original substances. Then ask them to identify the two mixtures that are the same even though the substances have been mixed in different proportions. **The mixtures with the powdered drink mix.**

Atoms as "Mini-Substances"

Find Out What Students Think

Students may think that...

... two or more elements on the periodic table can have the same atomic number. They may not realize that each element is unique and that an atomic number reveals the identity of an element.

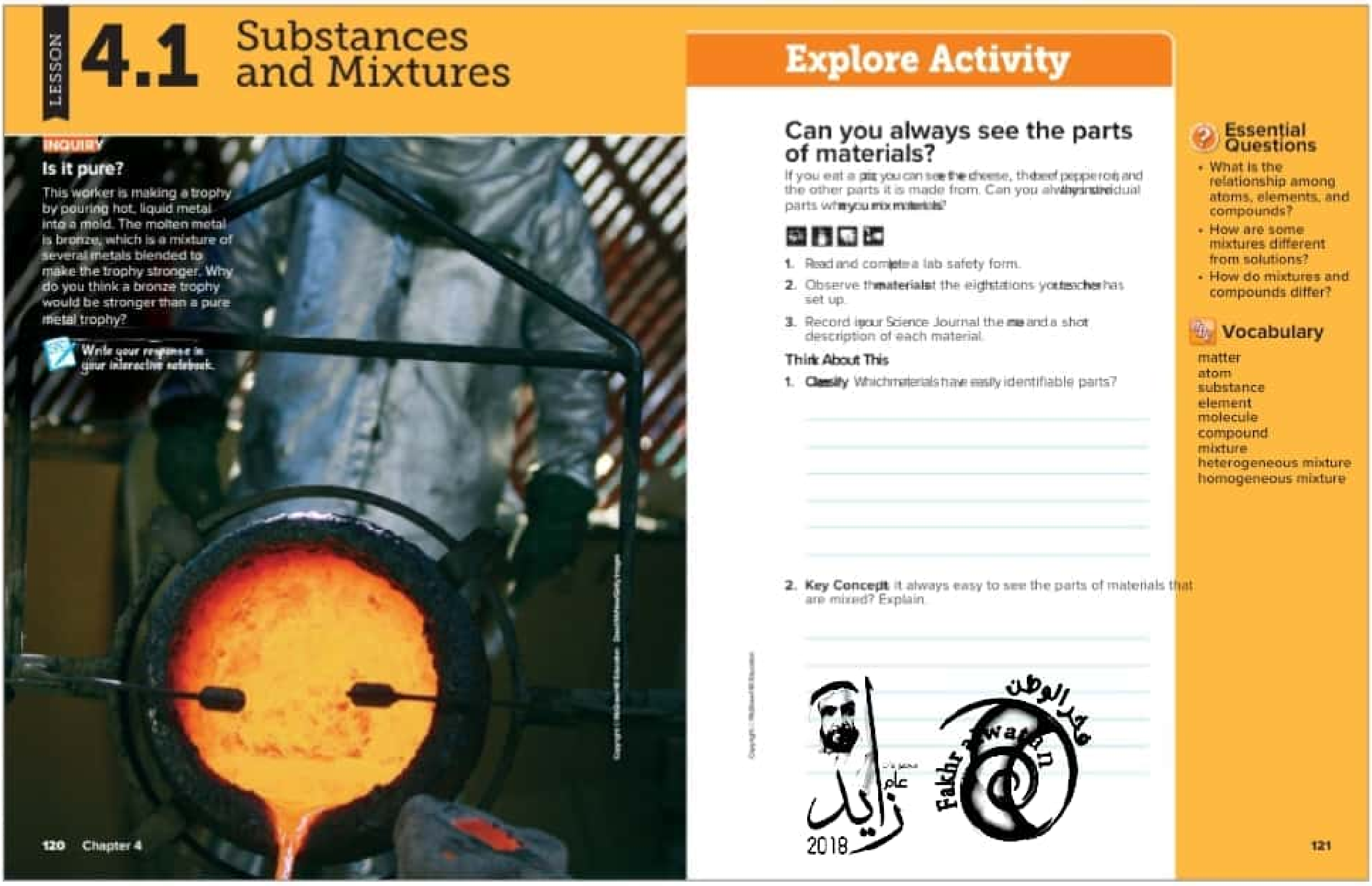
Discussion

Explain to students that the atomic number is the number of protons in the nucleus of an atom. Although the number of electrons and the number of neutrons may change (in ions and isotopes respectively), the number of protons remains constant. Have students turn to the periodic tables on the inside back covers of their textbooks. Ask them to locate boron (B) and carbon (C). **Ask:** What is the atomic number of boron? **5** What is the atomic number of carbon? **6** How many protons and neutrons does a normal boron atom have? **5 of each** How many protons and neutrons does a normal carbon atom have? **6 of each** **Ask:** Boron-11 is an isotope that has six neutrons. Does that mean it is the same as carbon? Why or why not? **No, it is not the same because boron-11 and carbon may have the same number of neutrons, but boron-11 still has only 5 protons.** Remind students that it is the number of protons that provides the atomic number and determines the identity of an element.

Promote Understanding

Activity Have students work together in pairs. They should select a group (all the elements in a column) or the nonmetals on the right side of the periodic table. Then they should include all the elements in that group on a chart that lists the number of protons, neutrons, and electrons in a single atom of each element. Also ask them to research one ion or one isotope for the elements in that group and include the number of protons, neutrons, and electrons for each one in a separate column. After students have completed their charts, have them discuss how the elements are alike and how they are different.

PAGE KEELEY SCIENCE PROBES



LESSON 4.1 Substances and Mixtures

INQUIRY

Is it pure?

This worker is making a trophy by pouring hot, liquid metal into a mold. The molten metal is bronze, which is a mixture of several metals blended to make the trophy stronger. Why do you think a bronze trophy would be stronger than a pure metal trophy?

Write your response in your interactive notebook.

120 Chapter 4

Explore Activity

Can you always see the parts of materials?

If you eat a pizza you can see the cheese, the beef pepperoni and the other parts it is made from. Can you always see individual parts when you mix materials?

1. Read and complete a lab safety form.
2. Observe the materials at the eight stations your teacher has set up.
3. Record in your Science Journal the name and a short description of each material.

Think About This

1. **Classify** Which materials have easily identifiable parts?
2. **Key Concept** Is it always easy to see the parts of materials that are mixed? Explain.

Essential Questions

- What is the relationship among atoms, elements, and compounds?
- How are some mixtures different from solutions?
- How do mixtures and compounds differ?

Vocabulary

matter
atom
substance
element
molecule
compound
mixture
heterogeneous mixture
homogeneous mixture

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INQUIRY

About the Photo **Is it pure?** The photo shows a worker making award trophies. The molten metal is bronze. Bronze is a metal alloy that is mostly copper with some other metals added for strength and durability, such as tin or aluminum. It also conducts heat and can be molded easily. These properties make bronze ideal for creating trophies, among other objects. Classifying matter and understanding the properties of materials can help you better understand their uses.

Guiding Questions

AL Describe one property of bronze.	*Answers will vary. Possible answers include: It can melt easily, it can be molded into different shapes, it is shiny, and so on.*
OL Why do you think a pure metal trophy would be different?	*It might not be as strong as the combination of metals and, as a result, might scratch or break more easily.*
BL Draw a conclusion about the physical property that makes it possible for the container to hold the bronze.	*Because the molten bronze is very hot, the container must have a higher melting point than the bronze to retain its shape.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

For this activity, gather a dozen objects from the classroom for students to describe, including both solids and liquids. If these are not available, bring them to class, show slides of various objects, or have students clip images from magazines. Explain that the objects are all examples of matter.

Vocabulary

Describing Matter

For this activity, gather a dozen objects from the classroom for students to describe, including both solids and liquids. If these are not available, bring them to class, show slides of various objects, or have students clip images from magazines. Explain that the objects are all examples of matter.

1. Have students examine the different objects. Ask each student to describe five of the objects, including their color, size, shape, weight, texture, and so on.

2. Discuss with students the kinds of words that they use to describe objects. Then ask them to consider other possible ways to describe matter beyond what they can observe with their senses.

Explore Activity

Can you always see the parts of materials?

Purpose

To investigate whether the parts that make up a material are always visible.

Materials

3 magnifying lenses, 3 plastic bowls, 5 150-mL beakers, 85 mL sugar, 115 mL sand, 150 mL vegetable oil, 350 mL water, 3 plastic spoons, marker, 8 index cards

Before You Begin

- Set up eight lab stations each with an labeled index card:
  Sugar bowl with 50 mL sugar
  Sand bowl with 50 mL sand
  Sugar and Sand bowl with 25 mL sugar and 25 mL sand
  Oil beaker with 100 mL oil
  Water beaker with 100 mL water
  Water and Oil beaker with 50 mL water and 50 mL oil
  Water and Sand beaker with 100 mL water and 40 mL sand
  Water and Sugar beaker with 100 mL very warm water and 10 mL sugar
- Stir the mixtures and allow them to set. Place magnifying lenses at stations with solid materials only so students can observe the parts. Include a plastic spoon so students can move the parts around and observe.

Guide the Investigation

- Before students begin, ask if they have ever stirred a drink mix into water or chocolate powder into milk. Ask them to describe the drink's appearance after they mixed parts.
- Encourage students to compare the lab materials before and after they are mixed.

Think About This

1. Accept any reasonable answers. The question prompts students think about what makes up matter. Students may note that sugar and sand are made of tiny grains. It is fairly easy to distinguish individual grains in the sugar-sand mixture. The oil/water and water/sand are also easy to distinguish.

2. **Key Concept** No; even though the water and sugar were mixed, the parts could not be seen individually.

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Word Origin

atom from Greek *atomos*; means "uncut"

What is matter?

Imagine how much fun it would be to go windsurfing! As the force of the wind pushes the sail, you lean back to balance the board. You feel the heat of the Sun and the spray of water against your face. Whether you are windsurfing on a lake or sitting at your desk in a classroom, everything around you is made of matter. **Matter** is *anything that has mass and takes up space.* Matter is everything you can see, such as water and trees. It is also some things you cannot see, such as air. You know that air is matter because you can feel it as it blows against your skin. You can see that it takes up space when it inflates a sail or a balloon.

Anything that does not have mass or volume is not matter. Types of energy, such as heat, sound, and electricity, are not matter. Forces, such as magnetism and gravity, also are not forms of matter.

Reading Check

1. Why are there so many types of matter?

What is matter made of?

The matter around you, including all solids, liquids, and gases, is made of atoms. An **atom** is *a small particle that is the building block of matter.* In this chapter, you will read that an atom is made of even smaller particles. There are many types of atoms. Each type of atom has a different number of smaller particles. You also will read that atoms can combine with each other in many ways. It is the many kinds of atoms and the ways they combine that form the different types of matter.

Classifying Matter

Because all the different types of matter around you are made of atoms, they must have characteristics in common. But why do all types of matter look and feel different? How is the matter that makes up a pure gold ring similar to the matter that makes up your favorite soda or even the matter that makes up your body? How are these types of matter different?

As the chart in **Figure 1** shows, scientists place matter into one of two groups–substances or mixtures. Pure gold is in one group. Soda and your body are in the other. What determines whether a type of matter is a substance or a mixture? The difference is in the composition.

Figure 1 You can classify matter as a substance or a mixture.

Matter
- Anything that has mass and takes up space
- Matter is made up of atoms.

Substances
- Matter with a composition that is always the same

Mixtures
- Matter that can vary in composition

What is a substance?

What is the difference between a gold ring and a can of soda? What is the difference between table salt and trail mix? Pure gold is always made up of the same type of atom, but soda is not. Similarly, table salt, or sodium chloride, is always made up of the same types of atoms, but trail mix is not. This is because sodium chloride and gold are substances. A **substance** is *matter with a composition that is always the same.* A certain substance always contains the same kinds of atoms in the same combination. Soda and trail mix are another type of matter that you will read about later in this lesson.

Reading Check

2. Why is gold classified as a substance?

Because gold is a substance, anything that is pure gold will have the same composition. Bars of gold are made of the same atoms as those in a pure gold ring, as shown in **Figure 2**. And, since sodium chloride is a substance, if you are salting your food in Ras Al Khama or in Abu Dhabi, the atoms that make up the salt will be the same. If the composition of a given substance changes, you will have a new substance.

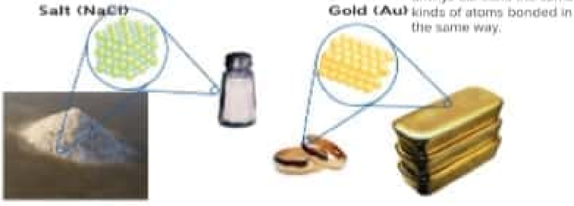


Figure 2 A substance always contains the same kinds of atoms bonded in the same way.

What is matter? What is matter made of?

Have students discuss the **Launch Lab**. Explain that all matter is made of parts we can't see. Have students read the paragraphs and answer these questions.

AL Is thermal energy matter?	*No. Energy does not have mass, so it is not matter.*
OL Why are there so many types of matter?	*because of the different kinds of atoms and the many ways they combine*

Word Origin

atom

Have students study the Greek origin of the word *atom*. **Ask: How do you think its Greek origin relates to the scientific use of atom?** *An atom is a small particle of an element that has the properties of that element. If you cut an atom, it loses the properties of that element.*

Classifying Matter

Matter is everywhere, but in order to understand it we must first be able to identify some basic characteristics, which can then be used to classify it into different groups. Brainstorm a list of ways to classify materials, such as by color, by size, by shape, by use, by number of parts, and so on. Then have students read the paragraphs and study the table in **Figure 1**. Use the following questions to guide your students' comprehension of this concept.

Guiding Questions

AL What are the two types of matter?	*substances and mixtures*
OL Why are soda and the human body in the same group, while gold is in a different group?	*Pure gold is a substance and has a fixed composition. Soda and the human body are mixtures and their composition can vary.*
BL Does the composition of one person's body vary from another's?	*Yes, even though the composition of the human body is similar, each person has a unique mixture of substances within them.*

What is a substance?

Have students read the paragraphs and study the images in **Figure 2**. Explain that no gold jewelry is truly pure. However, 24-kt gold, as shown in the photo, is 99.9 percent pure, which makes it the purest type.

After reading this section, some students may struggle with the concept that the composition of substances is constant. To demonstrate this, hold up a glass of water and a glass filled with ice cubes. Have students describe them. Explain that even though one is a solid and one is a liquid, they are both water and both have the same kinds of atoms that have combined in the same way. The amounts are different and the states are different, but the composition remains the same. Then ask the following questions.

Guiding Questions

AL What is a substance?	*A substance is matter with a composition that is always the same.*
OL Why is gold classified as a substance?	*Gold is classified as a substance because it has a fixed composition.*
BL How can astronomers claim that certain substances on Mars are similar to the same substances on Earth?	*Substances don't change depending on location. So water on Mars will have the same properties as water on Earth.*

Differentiated Instruction

AL **Elemental Objects** Provide pairs of students with a list of some of the elements on the periodic table. Have them circle elements they are familiar with. Ask them to brainstorm a list of objects that contain some of the elements they circled. Finally, have them discuss the v... objects that they identified. How many of the elements they identified are metals? How many are nonmetals? ... many are metalloids?

BL **Trends in the Periodic Table** Have students investigate one of the groups on the periodic table of elements. A... them to research the similarities and differences betwe... the elements in that group, such as the melting and bo... points, and their state at room temperature. Then have... write a brief report to describe their findings.

Teacher Toolbox

Reading Strategy

Write Pre-reading Questions Have students pose a list of questions they have about substances, compounds, ar... molecules before they continue to the next section. As... read the next two pages, have them refer to their ques... and write the answers for each one.

Teacher Demo

Design a Web Page Have students choose an element from the periodic tables in their textbooks. They shoul... research the element and draw the design for an Inter... Web site that identifies the element's name and prope... and includes suggestions for links.

Careers in Science

Nuclear Physicist Nuclear physicists study the structure and properties of atoms. They use extremely large machines known as particle accelerators to make new discoveries. These machines accelerate particles to ve... high speeds (sometimes near the speed of light— approximately 300,000 km/second) and cause them t... smash together. These types of experiments lead to discoveries about the building blocks of nature. Scient... discovered that protons and neutrons are made of sm... particles called quarks by particle acceleration.

Elements

Some substances, such as gold, are made of only one kind of atom. Others, such as sodium chloride, are made of more than one kind. An **element** is *a substance made of only one kind of atom.* All atoms of an element are alike, but atoms of one element are different from atoms of other elements. For example, the element gold is made of only gold atoms, and all gold atoms are alike. But gold atoms are different from silver atoms, oxygen atoms, and atoms of every other element.

Key Concept Check
3. How are atoms and elements related?

What is the smallest part of an element?

If you could break down an element into its smallest part, that part would be one atom. Most elements, such as carbon and silver, consist of a large group of individual atoms. Some elements, such as hydrogen and bromine, consist of molecules. A **molecule** is two or more atoms that are held together by chemical bonds and act as a unit. Examples of elements made of individual atoms and molecules are shown in **Figure 3**.

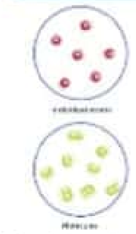


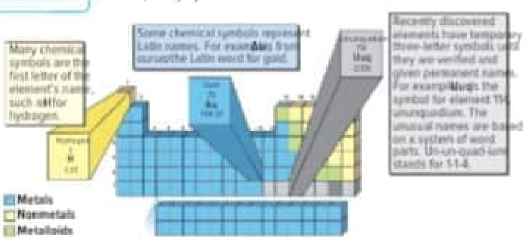
Figure 3 The smallest part of all elements is an atom. In some elements, the atoms are grouped into molecules.

Elements on the Periodic Table

You probably can name many elements, such as carbon, gold, and oxygen. Did you know that there are about 118 known elements? As shown in **Figure 4**, each element has a symbol, such as C for carbon, Au for gold, and O for oxygen. The periodic table printed in the back of this book gives other information about each element. You will learn more about elements in the next lesson.

Visual Check
4. What color are the blocks used for elements that have not yet been verified?

Figure 4 Element symbols have either one or two letters. Temporary symbols have three letters.



Compounds

Does it surprise you to learn that there are only about 115 different elements? After all, if you think about all the different things you see each day, you could probably name many more types of matter than this. Why are there so many kinds of matter when there are only about 115 elements? Most matter is made of atoms of different types of elements bonded together.

A **compound** is *a substance made of two or more elements that are chemically joined in a specific combination.* Because each compound is made of atoms in a specific combination, a compound is a substance. Pure water (H_2O) is a compound because every sample of pure water contains atoms of hydrogen and oxygen in the same combination—two hydrogen atoms to every oxygen atom. There are many types of matter because elements can join to form compounds.

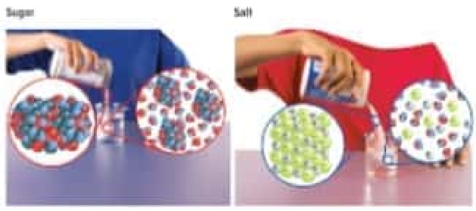
Key Concept Check
How do elements and compounds differ?

Molecules Recall that a molecule is two or more atoms that are held together by chemical bonds and that act as a unit. Is a molecule the smallest part of a compound? For many compounds, this is true. Many compounds exist as molecules. An example is water. In water, two hydrogen atoms and one oxygen atom always exist together and act as a unit. Carbon dioxide (CO_2) and table sugar ($C_{12}H_{22}O_{11}$) are also examples of compounds that are made of molecules.

However, as shown in **Figure 5**, some compounds are not made of molecules. In some compounds, such as table salt, or sodium chloride, no specific atoms travel together as a unit. However, table salt (NaCl) is still a substance because it always contains only sodium (Na) and chlorine (Cl) atoms.

Visual Check
6. What happens to the salt particles when the boy mixes the salt in the water? What do you think would happen if the water evaporated?

Figure 5 Sugar particles are molecules because they always travel together as a unit. Salt particles do not travel together as a unit.



Elements

Remind students about the "Building Block Bonanza" activity at the beginning of the lesson. Explain that if atoms were toy building blocks, an element would consist of a pile of blocks of the same color and shape, and a molecule would be two or more building blocks of different colors and/or shapes connected together.

Have students read the paragraphs and study Figure 3.

The periodic table shows all the elements that have been discovered and how they are different from one another, much the same way an instruction booklet for a set of toy building blocks could show the different kinds of pieces that come with the set. Then ask students the following questions to assess their comprehension.

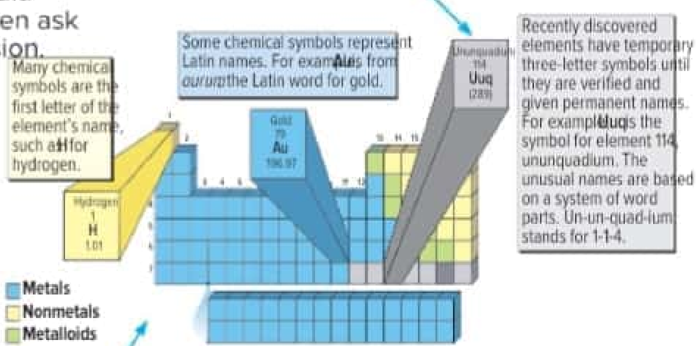
Guiding Questions

AL What is the difference between an atom and a molecule?	*An atom is a single particle, while a molecule is two more atoms that are held together by chemical bonds and act as a unit.*
OL How are atoms and elements related?	*Each element is made of a different kind of atom.*
BL Why might it be important for scientists to know how elements are similar or different?	*It might help them know if one element could be used the same way as another or how elements will react when they are chemically bonded together.*

Visual Literacy: Elements

Explain to students that the periodic table does not only list the names of the elements, it provides other information as well. For example, it classifies them as metals, non-metals, or metalloids. Have students study the image in **Figure 4**. Then ask the following questions.

Ask: What color are the blocks used for elements that have not yet been verified? *gray*



Ask: Of the three classes of elements, which has the greatest number of elements: metals, nonmetals, or metalloids? *metals*

Compounds

Have students read the paragraphs and **Figure 5**. Students will later learn that the two types of compounds described here are covalent compounds (such as sugar, carbon dioxide, and water) and ionic compounds (such as sodium chloride).

Remind students about the "Building Block Bonanza" activity at the beginning of the lesson. Explain that if compounds were toy building blocks, a compound would consist of a pile of blocks with the same kinds of pieces attached in the same way. Because atoms can combine in many different ways, there are many kinds of compounds. Listing them all in a table, the way elements are listed on the periodic table, is impossible. Ask these questions to assess students' comprehension.

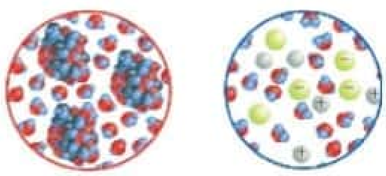
Guiding Questions

AL What is a compound?	*A compound is a substance made of two or more elements that are chemically joined in a specific combination.*
OL How do elements and compounds differ?	*Elements are made of just one type of atom. Compounds are made of two or more elements that are bonded.*
OL Is H_2O a molecule, a compound, or both? Explain your answer	*Both. It is a molecule because it has three atoms held together by chemical bonds acting as a unit, and it is a compound because it consists of two elements, hydrogen and oxygen, always bonded in the same combination.*

Visual Literacy: Compounds

Write the elements in sugar (carbon, hydrogen, and oxygen) and salt (sodium and chlorine) on chart paper or the board. Explain that the elements in sugar combine in a different way than the elements in salt do. Then have students study **Figure 5**. Ask them to compare the two types of compounds

Sugar Salt



Ask: Describe the difference between the sugar particles and the salt particles in this image. *Each sugar particle moves through the water as a clump with the elements stuck together. The elements of the salt particles move through the water separately.*

Ask: How are salt particles and sugar particles similar? *They are both compounds because they are chemically bonded elements.* **How are they different?** *They contain different elements. The elements of sugar travel as a unit, but the elements of salt do not.*

Ask: What happens to the salt particles when the boy mixes the salt in water? *The salt particles separate and mix evenly among the water particles.* **What do you think would happen if the water evaporated?** *The negative and positive salt particles would attract each other and reform salt.*

Differentiated Instruction

AL Play a Word Game Have students write a paragraph t summarize what they have read. They should leave a b space for each vocabulary word included in their paragraphs. Then have them swap their paragraphs wi those of other students to fill in the blanks.

BL Everyday Formulas Provide students with several chemical formulas for everyday items, such as CH_3COO (acetic acid), NH_3 (ammonia), C_3H_7OH (rubbing alcohol HNO_3 (nitric acid). Ask them to do Internet research to identify the compound and find one use for it. For exar acetic acid is in vinegar and nitric acid is used to make fertilizers. Ask them to create a poster that has a pictur each item along with a label that identifies it by its che formula.

Teacher Toolbo

Reading Strategy

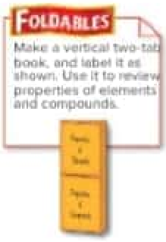
I Know It Is. Have students write sentences about *matt elements, compounds, atoms, molecules,* and *substan* Each sentence should start with "I know it is (a/an) _________ because it..." to define that term. For examp know it is matter because it has mass and takes up sp

Real-World Science

What Is Electrolysis? Electrolysis is the process of using electricity to trigger a chemical change. For example, w an electric current passes through water, it breaks the bonds between hydrogen and oxygen. The hydrogen oxygen separate into gases and new substances form Scientists are working on ways to use electrolysis to produce hydrogen from water to run a hydrogen-fuel c Maybe in the future, we'll ride in cars that run on wate instead of gasoline!

Fun Fact

Chemical Formulas for Proteins Our bodies rely on the proteins found in meats and dairy products. Proteins a complicated compounds made carbon, hydrogen and elements. Each molecule is extremely large and has a number of atoms. As a result, proteins have complex chemical formulas. For example, hemoglobin, the chen that carries oxygen in blood, is made of protein. There different types of hemoglobin, but the formula for the common one is $C_{2952}H_{4664}N_{812}O_{832}S_8Fe_4$



Make a vertical two-tab book, and label it as shown. Use it to review properties of elements and compounds.

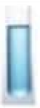
Properties of Compounds How would you describe sodium chloride, or table salt? The properties of a compound, such as table salt, are usually different from the properties of the elements from which it is made. Table salt, for example, is made of the elements sodium and chlorine. Sodium is a soft metal, and chlorine is a poisonous green gas. These properties are much different from the table salt you sprinkle on food!

Chemical Formulas Just as elements have chemical symbols, compounds have chemical formulas. A formula includes the symbols of each element in the compound. It also includes numbers, called subscripts, that show the ratio of the elements in the compound. You can see the formulas for some compounds in **Table 1.**

Different Combinations of Atoms Sometimes the same elements combine to form different compounds. For example, nitrogen and oxygen can form six different compounds. The chemical formulas are N_2O, NO, NO_2, N_2O_3, N_2O_4, and N_2O_5. They contain the same elements, but because the combinations of atoms are different, each compound has different properties, as shown in **Table 1.**

Table 1 Atoms can combine in different ways and form different compounds.

Table 1

Formula and Molecular Structure	Properties/Functions
N_2O  Nitrous oxide	 colorless gas used as an anesthetic
NO_2  Nitrogen dioxide	 brown gas, toxic, air pollutant
N_2O_3  Dinitrogen trioxide	 blue liquid

What is a mixture?

By looking at the glass of clear liquid in **Figure 6**, can you tell whether it is lemon-lime soda or water? Lemon-lime soda is almost clear, and someone might confuse it with water, which is a substance. Recall that a substance is matter with a composition that is always the same. However, sodas are a combination of substances such as water, carbon dioxide, sugar, and other compounds. In fact, most solids, liquids, and gases you see each day are mixtures. A **mixture** is *matter that can vary in composition.* It is made of two or more substances that are blended but are not chemically bonded.

Figure 6 It's hard to tell which is in the glass—pure water (a substance) or lemon-lime soda (a mixture).

What would happen if you added more sugar to a glass of soda? You would still have soda, but it would be sweeter. Changing the amount of one substance in a mixture does not change the identity of the mixture or its individual substances.

Air and tap water are also mixtures. Air is a mixture of nitrogen, oxygen, and other substances. However, the composition of air can vary. Air in a scuba tank usually contains more oxygen and less of the other substances. Tap water might look like pure water, but it is a mixture of pure water (H_2O) and small amounts of other substances. Since the substances that make up tap water are not bonded together, the composition of tap water can vary. This is true for all mixtures.

Describe

List the main ideas from this section in the lines below.

Compounds (continued)

Pour table salt into a clear container, such as a glass or a plastic bowl. Ask students to describe the salt, including its color, its shape, and its texture. Ask them if they think salt is an element or something else. Explain that salt is a compound. It is made of two elements sodium (Na) and chloride (Cl). Then have students read the paragraphs. Ask the following questions to informally assess their understanding.

Guiding Questions

AL What does a subscript show in a chemical formula?	*It shows the ratio of elements that make up a compound.*
OL How do elements and compounds differ?	*the symbols of each element in the compound and the ratio of elements in the compound*
OL Does a compound of one hydrogen atom and two oxygen atoms have the same properties as a compound of two hydrogen atoms and two oxygen atoms? Why or why not?	*No, because those are two different compounds with different arrangements and different properties.*
BL Rewrite the following elements in a chemical formula. HHOCCOHCH OOCCHHHCHOHHOHH	*Students should rearrange the elements to show only C, H, and O. Next students should count the number of each element and assign a subscript. The answer is $C_6H_{12}O_6$—sugar. Students will not know the conventions for the order of elements. Accept variations in the order of C, H, and O with the correct subscripts. Explain that in more advanced chemistry classes they will learn the order for writing elements in chemical formulas.*

Visual Literacy: Table 1

Have students compare the compounds shown in **Table 1**. Discuss how changing the ratio of each element changes the resulting compounds. For example, nitrous oxide (N_2O) is a gas that dentists use to sedate patients. In a controlled dental environment most patients can have this gas in small quantities with limited adverse affects. Another gas, nitrogen dioxide (NO_2), commonly found in polluted air, has been reported to affect human health when present even in small quantities. Some studies report adverse health effects at nitrogen dioxide concentrations of 200 parts per billion.

Types of Mixtures

How do trail mix, soda, and air differ? One difference is that trail mix is a solid, soda is a liquid, and air is a gas. This tells you that a mixture can be any state of matter. Another difference is that you can see the **individual** parts that make up trail mix, but you cannot see the parts that make up soda or air. This is because trail mix is a different type of mixture than soda and air. There are two types of mixtures–heterogeneous and homogeneous. The prefix hetero- means "different," and the prefix homomeans "the same." Heterogeneous and homogeneous mixtures differ in how evenly the substances that compose them are mixed.

Academic Vocabulary
individual (adjective) single; separate

Heterogeneous Mixtures

Suppose you take a bag of trail mix and pour it into two identical bowls. What might you notice? At first glance, each bowl appears the same. However, if you look closely, you might notice that one bowl has more nuts and another bowl has more raisins. The contents of the bowls differ because trail mix is a heterogeneous mixture. **heterogeneous mixture** *mixture in which the substances are not evenly mixed.* Therefore, if you take two samples from the same mixture, such as trail mix, the samples might have different amounts of the individual substances. The mixtures shown in Figure 7 are examples of heterogeneous mixtures.

Reading Check
7. Explain why vegetable soup is classified as a heterogeneous mixture.

Figure 7 The different parts of a heterogeneous mixture are not evenly mixed.

The numbers of peanuts, pretzels, raisins, and other types of food in trail mix could change, and it still would be trail mix.

You know that granite is a heterogeneous mixture because you can see the different minerals from which it is made.

With a microscope, you would be able to see that smoke is a heterogeneous mixture of gas and solid particles.

Homogeneous Mixtures

If you pour soda into two glasses, the amounts of water, carbon dioxide, sugar, and other substances in the mixture would be the same in both glasses. Soda is an example of a **homogeneous mixture** *mixture in which two or more substances are evenly mixed, but not bonded together.*

Figure 8 Salt is soluble in water. Pepper is insoluble in water. The pepper and water is a mixture, but not a solution.

Evenly Mixed Parts In a homogeneous mixture, the substances are so small and evenly mixed that you cannot see the boundaries between substances in the mixture. Brass, a mixture of copper and zinc, is a homogeneous mixture because the copper atoms and the zinc atoms are evenly mixed. You cannot see the boundaries between the different types of substances, even under most microscopes. Lemonade and air are also examples of homogeneous mixtures for the same reason.

Solution Another name for a homogeneous mixture is a solution. A solution is made of two parts–a solvent and one or more solutes. The solvent is the substance that is present in the largest amount. The solutes dissolve, or break apart, and mix evenly in the solvent. In Figure 8, water is the solvent, and salt is the solute. Salt is soluble in water. Notice also in the figure that pepper does not dissolve in water. No solution forms between pepper and water. Pepper is insoluble in water.

Key Concept Check
How are some mixtures different from solutions?

Other examples of solutions are described in Figure 9. Note that all three states of matter–solid, liquid, and gas–can be a solvent or a solute in a solution.

Figure 9 Solids, liquids, and gases can combine to make solutions.

This trumpet is made of brass, a solution of zinc and copper and solid.

The natural gas used in a gas stove is a solution of methane, ethane, and other gases.

This ammonia cleaner is a solution of water and ammonia gas.

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Types of Mixtures

Students may not realize how many different kinds of mixtures they encounter everyday. Have them discuss possible mixtures from in and around the school, such as the concrete and brick that make up the building, food from the cafeteria that is made from a mix of different ingredients, the air we breathe, and so on. Have students read the paragraph and answer the following questions to assess their comprehension. Then ask them the following questions

Guiding Questions

AL	Do mixtures only take the form of a liquid?	No, mixtures can be solids and gases, too.
OL	How do homogeneous mixtures differ from heterogeneous mixtures?	They differ in how evenly the substances that make them up mix together.
BL	If you separated all the different kinds of food in a bowl of trail mix, would you be dividing them into pure substances?	No, because the nuts, raisins, and other kinds of food in trail mix are mixtures themselves.

Heterogeneous Mixtures

Have students examine the images in Figure 7. Ask them to describe the similarities and differences between the trail mix, the rock, and the smoke. For example, two are solids and one is a gas. Also all three are examples of mixtures, but the parts that make up the trail mix and the rock can clearly be seen and the parts that make up the smoke cannot. Then have students read the paragraph and ask the following question to assess their understanding.

Guiding Questions

AL	Why is trail mix a heterogeneous mixture?	The substances in trail mix do not mix evenly.
OL	Explain why vegetable soup is classified as a heterogeneous mixture.	The contents of the soup are not always the same. Two bowls of the soup may have different amounts of the parts that make up the soup.
BL	Does every bag of trail mix have the same composition?	No, because trail mix is a heterogeneous mixture, each bag has a different number of each component, or even different substances.

OL If an atom bonded with a compound, would the properties of the compound remain the same? *No, because when an atom bonds with a compound, it creates a new substance with its own set of properties.*

BL Would adding extra sugar to a pitcher of lemonade change the identity of the solution? Why or why not? *No, because the composition (water, sugar, lemons) of a solution could change without changing its identity. Adding more sugar would not change lemonade to a different kind of solution.*

Separating Mixtures

Have students observe as you combine salt with water to make a solution. Ask them if it is possible to separate the parts in the mixture. yes Then have them predict ways to do this. *Heat the solution and let the water evaporate, leaving the salt behind, because water and salt have different boiling points.* Then have students read the paragraphs and answer the following questions.

Guiding Questions

AL Can you separate the parts of a mixture using a physical process? Can you separate the parts of a compound using a physical process? *yes; no*

OL Name three methods of separating heterogeneous mixtures. *Sample answers include using a strainer; picking out large, solid pieces; and using a magnet to remove magnetic parts.*

Review Vocabulary

chemical change

Have students review the definition of chemical change.

Ask: Does a chemical change affect the bonds between atoms? Why or why not? *Yes, because when a chemical change occurs substances change into other substances; in order to do that atoms must break their bonds and form new ones.*

Visual Literacy: Separating Mixtures

Have students examine the three photographs in **Figure 10**, which show physical methods of separating the parts of mixtures. Explain that it does not matter if the mixture is a solid, liquid, or a gas, you can find a way to separate the different parts using physical methods even if those methods are somewhat complex. For example, blood is a heterogeneous mixture. In medical labs, researchers must separate samples of blood into different parts to study them. To do so, they use a machine called a centrifuge to spin the samples and separate the parts. Have students answer the following questions to assess their understanding of the images and separating mixtures.

Ask: How could you separate the small rocks and dirt that passed through the strainer on the left? *Sample answer: Pour the strained part through a different strainer with smaller openings.*

Ask: If you shake the oil and vinegar mixture up for a long time, won't the oil dissolve? *No, oil and vinegar combine to make a heterogeneous mixture. If you keep shaking it, the oil will break up into small pieces at first but after you stop shaking it will separate back into two layers.*

Differentiated Instruction

AL **Separating the Nuts and Bolts** Prepare a mixture of odds and ends (such as buttons, paper clips, rocks, era along with soil or sand in water. Have students create to separate the parts of the mixture. Once they have a ask them to create a flow chart to explain their approa

BL **Making Crystals** Have pairs of students prepare shallow pans with a solution of water, Epsom salt, and coloring to demonstrate the process of crystallization. mixing the solution, they should pour it into in their par and leave them in a sunny area, such as a windowsill. water will evaporate over several days, forming crystal Have students write a brief report to explain what happ to the mixture. The reports should indicate that the init mixture was a heterogeneous mixture. Students should support this knowledge with the fact that the mixture w separated by a physical change (evaporation).

Teacher Toolbox

Careers in Science

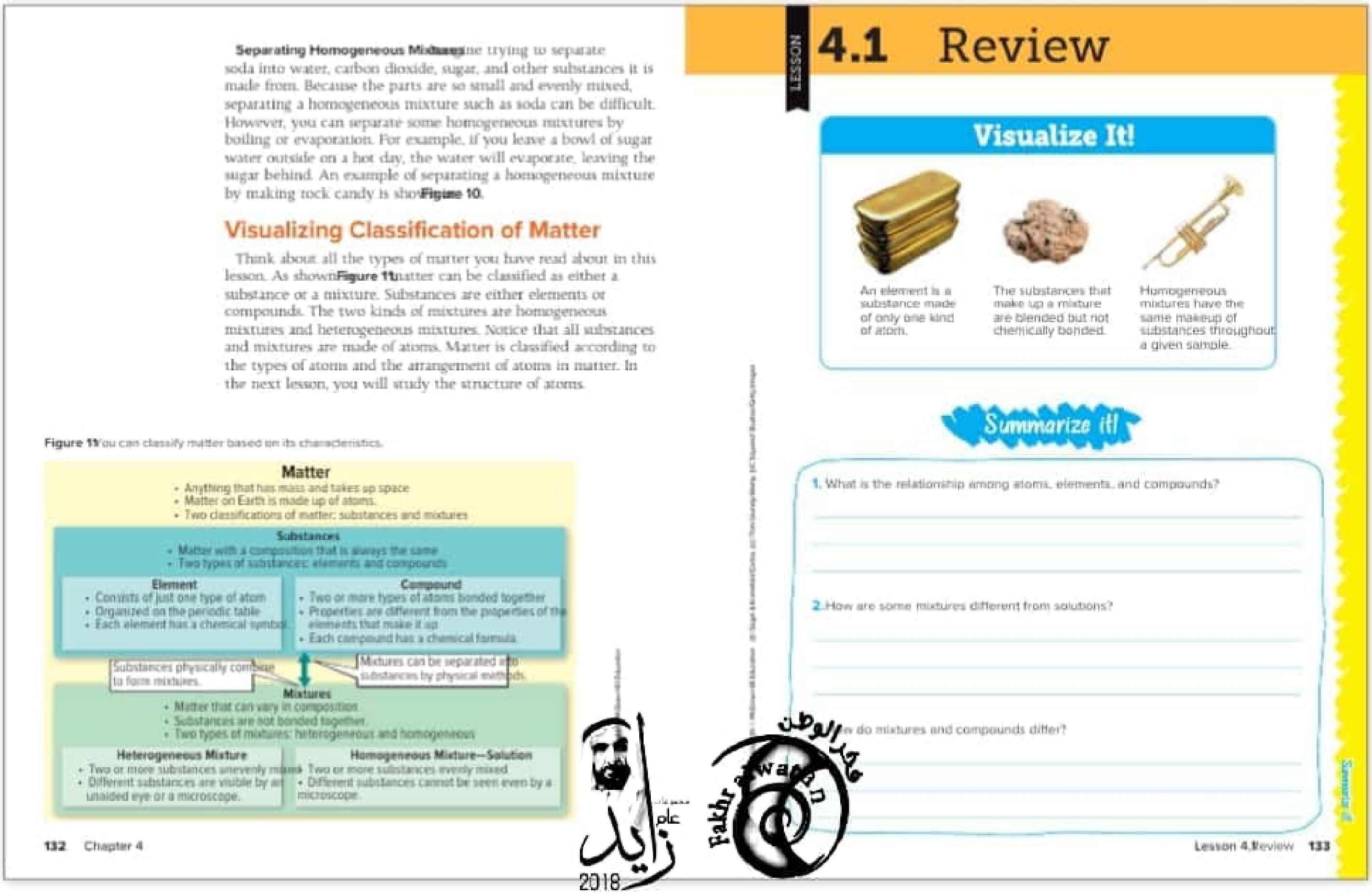
Factory Workers To keep oil and vinegar from separating salad dressings, factory workers add an ingredient kno as an emulsifier to the mixture. The emulsifier prevent oil and vinegar from splitting into separate layers by suspending the droplets of one liquid into the other.

Real-World Science

Kitchen Separations Separating the parts of a mixture is common step when preparing food. For instance, cool often separate the yolk of an egg from the white part throw away the shell. We also separate mixtures when shells are removed from nuts, or peels are pulled back bananas. Other examples include juicing fruit, peeling skins from potatoes and carrots, cutting fat off of meat filtering grounds from a pot of coffee.

Reading Strategy

Main Idea and Supporting Details Have students reread the sections on separating mixtures. Ask them to com a main idea and supporting details chart to explain tha mixtures can be separated using physical methods. As students to name and describe some of these method



Separating Homogeneous Mixtures Imagine trying to separate soda into water, carbon dioxide, sugar, and other substances it is made from. Because the parts are so small and evenly mixed, separating a homogeneous mixture such as soda can be difficult. However, you can separate some homogeneous mixtures by boiling or evaporation. For example, if you leave a bowl of sugar water outside on a hot day, the water will evaporate, leaving the sugar behind. An example of separating a homogeneous mixture by making rock candy is shown in **Figure 10**.

Visualizing Classification of Matter

Think about all the types of matter you have read about in this lesson. As shown in **Figure 11**, matter can be classified as either a substance or a mixture. Substances are either elements or compounds. The two kinds of mixtures are homogeneous mixtures and heterogeneous mixtures. Notice that all substances and mixtures are made of atoms. Matter is classified according to the types of atoms and the arrangement of atoms in matter. In the next lesson, you will study the structure of atoms.

Figure 11 You can classify matter based on its characteristics.

132 Chapter 4

LESSON 4.1 Review

Visualize It!

Summarize it!

1. What is the relationship among atoms, elements, and compounds?

2. How are some mixtures different from solutions?

3. How do mixtures and compounds differ?

Lesson 4 Review 133

Separating Homogeneous Mixtures

Have students take a second look at the photograph of rock candy in **Figure 10**. Explain that the formation of crystals is one example of separating a homogeneous mixture. Another example of this can happen in a solution of Epsom salts and water. It occurs when the solution is boiled until the water evaporates and leaves behind salt particles that form crystals. Have students read the paragraph and answer the following questions.

Guiding Questions

AL Is it more difficult to separate a heterogeneous or a homogeneous mixture?	*Homogeneous mixtures are more difficult to separate because they are evenly mixed.*
OL Name one method of separating homogeneous mixtures.	*Answers may include filtering, boiling point, melting point, magnetism, or evaporation.*
BL In order to separate components in a homogeneous mixture, what must be true of the solutes and solvent?	*They must have boiling points that are significantly different.*

Visualizing Classification of Matter

Have students read the paragraph to review the different types of matter. Then ask the following questions.

Guiding Questions

AL What are the two types of matter?	*Substances and mixtures*
OL Describe the differences between substances and mixtures.	*Substances are made of one or more types of atoms in the same combination. Mixtures are made of two or more substances that are not bonded together. The combinations of the substances can vary.*
BL What question can you ask that will immediately tell you if a mixture is heterogeneous or homogeneous mixture?	*Are the substances within the mixture evenly mixed? If yes, it's a homogeneous mixture (a solution); if no, then it's heterogeneous mixture.*

Visual Literacy: Classifying Matter

Have students study the chart **Figure 11**. Explain that organizing all the information from this lesson on a chart makes it much easier to compare and contrast the difference between substances and mixtures, elements and compounds, and heterogeneous and homogeneous mixtures. Use the following questions to help students understand the chart.

Ask: **What is a quick "rule of thumb" to determine if a substance is an element or a compound?** *If it has one type of atom, it's an element; otherwise, it's a compound.*

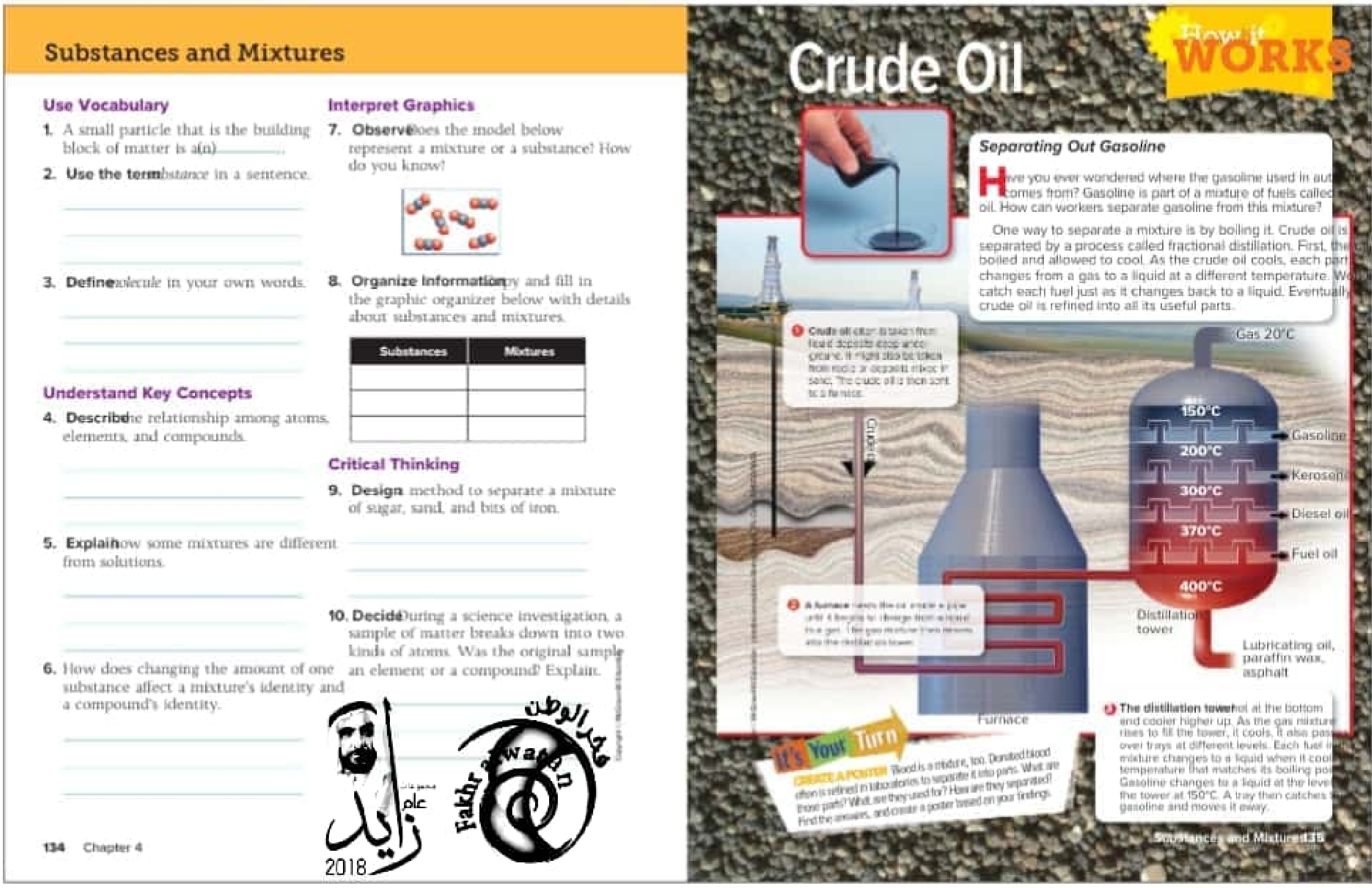
Ask: *What type of matter is not a mixture, but contains two or more atoms? a compound.*

Ask: *What indicates that a material made of more than one element is a mixture? If it is made of atoms or compounds that combine together, but do not bond.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** **Which Key Concept does each image relate to?**

Teacher Notes



Substances and Mixtures

Use Vocabulary

1. A small particle that is the building block of matter is a(n) ________.
2. **Use the term** substance in a sentence.
3. **Define** molecule in your own words.

Understand Key Concepts

4. **Describe** the relationship among atoms, elements, and compounds.
5. **Explain** how some mixtures are different from solutions.
6. How does changing the amount of one substance affect a mixture's identity and a compound's identity?

Interpret Graphics

7. **Observe** Does the model below represent a mixture or a substance? How do you know?
8. **Organize Information** Copy and fill in the graphic organizer below with details about substances and mixtures.

Substances	Mixtures

Critical Thinking

9. **Design** a method to separate a mixture of sugar, sand, and bits of iron.
10. **Decide** During a science investigation, a sample of matter breaks down into two kinds of atoms. Was the original sample an element or a compound? Explain.

Use Vocabulary

1. atom

2. Sample answer: Hydrogen is a substance because its composition is always the same.

3. Sample answer: A molecule is a group of atoms that are chemically bonded and act as a unit.

Understand Key Concepts

4. An element is composed of just one kind of atom. A compound is composed of more than one element, each of which is composed of a different type of atom.

5. A heterogeneous mixture is not a solution because the substances that make up a heterogeneous mixture are not evenly mixed, but the substances that make up a solution are evenly mixed.

6. If the amount of one substance was changed in a mixture, the identity of the mixture does not change. If another atom bonded with a compound, the compound's identity would change. For example, if another oxygen atom was added to water (H_2O), hydrogen peroxide (H_2O_2), a new substance with different properties, is created.

Interpret Graphics

7. The model represents a substance because all of the particles are combined in the same way.

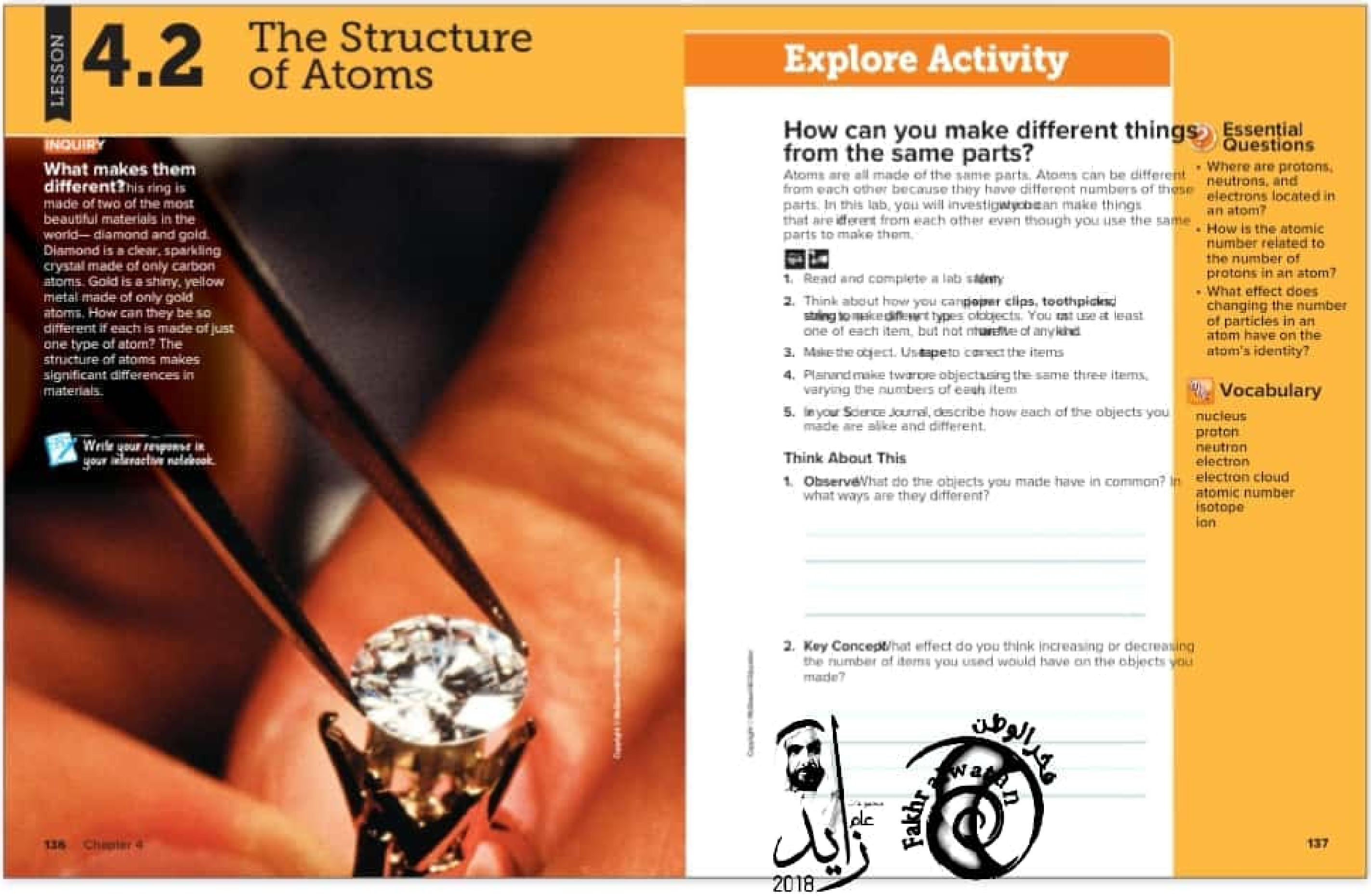
8.

Substances	Mixtures
Made of one or more types of atoms	Made of two or more substances that are not bonded together
Has a fixed composition	Composition can vary
Can be either an element or a compound	Can be mixed evenly or unevenly

Critical Thinking

9. First, use a magnet to remove the iron. Next, stir the remaining sugar and sand into water. The sugar will dissolve, and then filter out the sand. You can boil the water away, leaving the sugar.

10. A compound. Elements are made of only one kind of atom.



LESSON 4.2 The Structure of Atoms

INQUIRY

What makes them different? This ring is made of two of the most beautiful materials in the world— diamond and gold. Diamond is a clear, sparkling crystal made of only carbon atoms. Gold is a shiny, yellow metal made of only gold atoms. How can they be so different if each is made of just one type of atom? The structure of atoms makes significant differences in materials.

Write your response in your interactive notebook.

Explore Activity

How can you make different things from the same parts?

Atoms are all made of the same parts. Atoms can be different from each other because they have different numbers of these parts. In this lab, you will investigate how you can make things that are different from each other even though you use the same parts to make them.

1. Read and complete a lab safety form.
2. Think about how you can use paper clips, toothpicks, and string to make different types of objects. You must use at least one of each item, but not more than five of any kind.
3. Make the object. Use tape to connect the items.
4. Plan and make two more objects using the same three items, varying the numbers of each item.
5. In your Science Journal, describe how each of the objects you made are alike and different.

Think About This

1. **Observe** What do the objects you made have in common? In what ways are they different?
2. **Key Concept** What effect do you think increasing or decreasing the number of items you used would have on the objects you made?

Essential Questions

- Where are protons, neutrons, and electrons located in an atom?
- How is the atomic number related to the number of protons in an atom?
- What effect does changing the number of particles in an atom have on the atom's identity?

Vocabulary

nucleus
proton
neutron
electron
electron cloud
atomic number
isotope
ion

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INQUIRY

About the Photo **What makes them different?** One of the most amazing aspects of nature is that the structure of atoms, which are on a very tiny scale, has an enormous impact on the elements they create. Understanding atoms can help you understand the elements and their properties, how they react with one another, and how they can be used.

Guiding Questions

AL What two of the elements used to make the ring in this picture?	*carbon and gold; Gold alone is not very strong, therefore, most gold is mixed with silver to provide greater strength for a piece of jewelry.*
OL Looking at the picture, what are some properties of gold?	*Sample answers include it being shiny, yellow, and can be shaped and molded without breaking.*
BL Do you think a diamond could be used to make a ring band and gold be used to make a stone? Why or why not?	*Probably not, because diamonds and gold have very different properties. These properties make them suitable only for particular uses.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

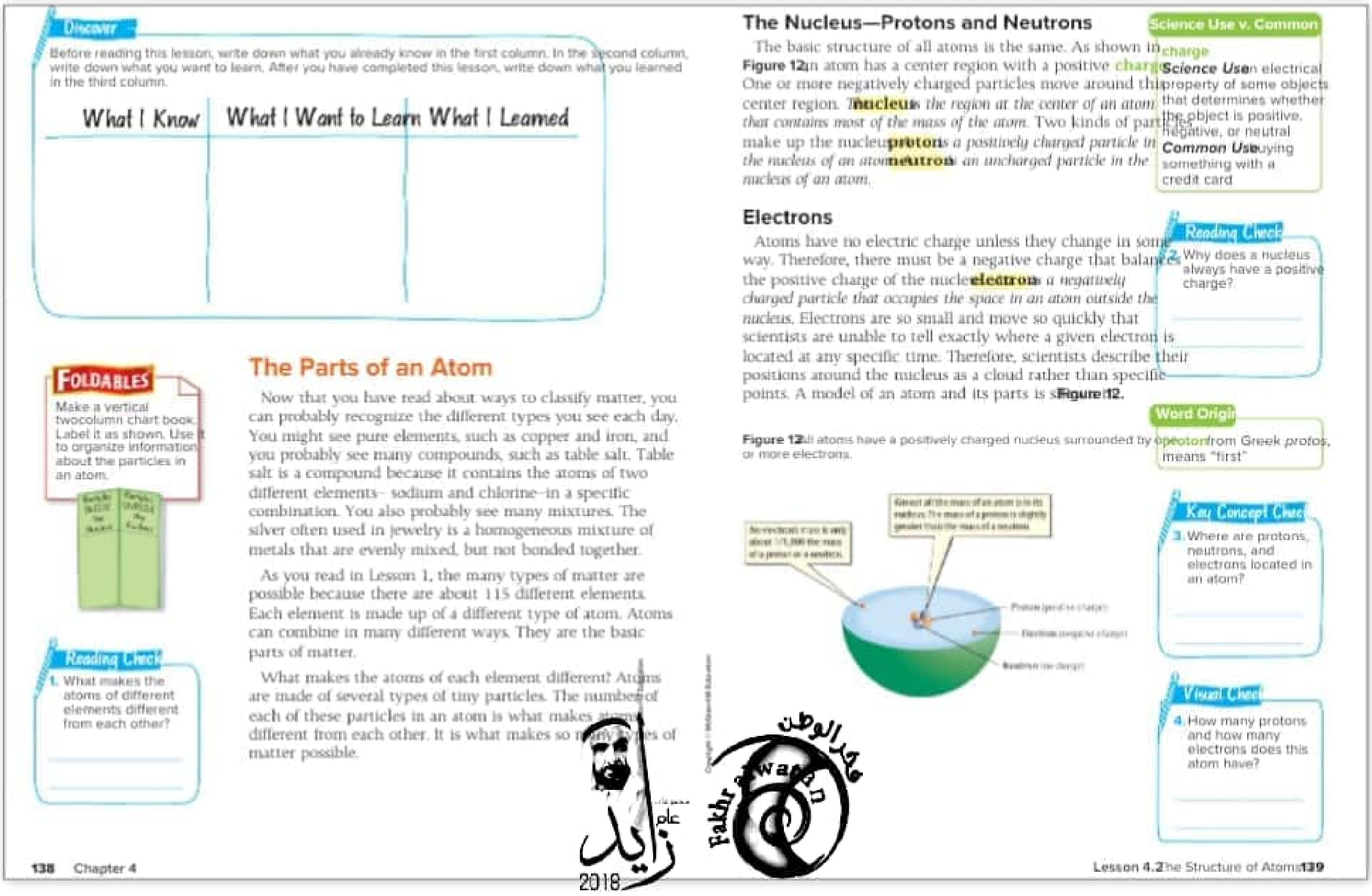
Essential Questions

After this lesson, students should understand the Key Concepts and be able to answer these questions. Have students write each question in their Science Journals. Revisit each question as you cover its relevant content.

Vocabulary

Predicting the Particles in an Atom

1. Write the terms atom and element on the board.
2. Ask: **Think back to the last lesson. What is the definition of atom? What is the definition of element?** *An atom is a small particle that is the building block of matter. An element is a substance made of only one kind of atom.*
3. Remind students that they learned that atoms contain even smaller particles. Ask them to study the list of vocabulary words on this page. Ask them to predict which words are



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

FOLDABLES

Make a vertical twocolumn chart book. Label it as shown. Use it to organize information about the particles in an atom.

The Parts of an Atom

Now that you have read about ways to classify matter, you can probably recognize the different types you see each day. You might see pure elements, such as copper and iron, and you probably see many compounds, such as table salt. Table salt is a compound because it contains the atoms of two different elements– sodium and chlorine–in a specific combination. You also probably see many mixtures. The silver often used in jewelry is a homogeneous mixture of metals that are evenly mixed, but not bonded together.

As you read in Lesson 1, the many types of matter are possible because there are about 115 different elements. Each element is made up of a different type of atom. Atoms can combine in many different ways. They are the basic parts of matter.

What makes the atoms of each element different? Atoms are made of several types of tiny particles. The number of each of these particles in an atom is what makes atoms different from each other. It is what makes so many types of matter possible.

Reading Check

1. What makes the atoms of different elements different from each other?

138 Chapter 4

The Nucleus—Protons and Neutrons

The basic structure of all atoms is the same. As shown in **Figure 12**, an atom has a center region with a positive charge. One or more negatively charged particles move around this center region. The **nucleus** is *the region at the center of an atom that contains most of the mass of the atom.* Two kinds of particles make up the nucleus. A **proton** is *a positively charged particle in the nucleus of an atom.* A **neutron** is *an uncharged particle in the nucleus of an atom.*

Science Use v. Common Use

charge

Science Use an electrical property of some objects that determines whether the object is positive, negative, or neutral

Common Use buying something with a credit card

Electrons

Atoms have no electric charge unless they change in some way. Therefore, there must be a negative charge that balances the positive charge of the nucleus. An **electron** is *a negatively charged particle that occupies the space in an atom outside the nucleus.* Electrons are so small and move so quickly that scientists are unable to tell exactly where a given electron is located at any specific time. Therefore, scientists describe their positions around the nucleus as a cloud rather than specific points. A model of an atom and its parts is shown in **Figure 12.**

Reading Check

2. Why does a nucleus always have a positive charge?

Word Origin

proton from Greek *protos*, means "first"

Figure 12 All atoms have a positively charged nucleus surrounded by one or more electrons.

Key Concept Check

3. Where are protons, neutrons, and electrons located in an atom?

Visual Check

4. How many protons and how many electrons does this atom have?

Lesson 4.2 The Structure of Atoms 139

The Parts of an Atom

Remind students that atoms are the smallest particles of elements. For example, a bar of silver is made of millions upon millions of silver atoms. Oxygen in the air is made of many, many, many oxygen atoms. An element cannot be broken down into anything smaller than an atom and still retain its identity. However, atoms contain even smaller particles. Have students read the paragraphs and answer the following question.

Guiding Questions

OL What makes the atoms of different elements different from each other?	*Atoms of different elements are made of different numbers of particles.*

The Nucleus—Protons and Neutrons, Electrons

Have students discuss the Launch Lab. Explain that all atoms have the same parts. However, the numbers and combinations of these parts can differ. Have students read this page. Then complete the vocabulary activities and ask the guiding questions to assess students' understanding of the three atomic particles.

Science Use v. Common Use

charge

Ask: Are the science and common uses similar or different?

WORD ORIGIN

proton

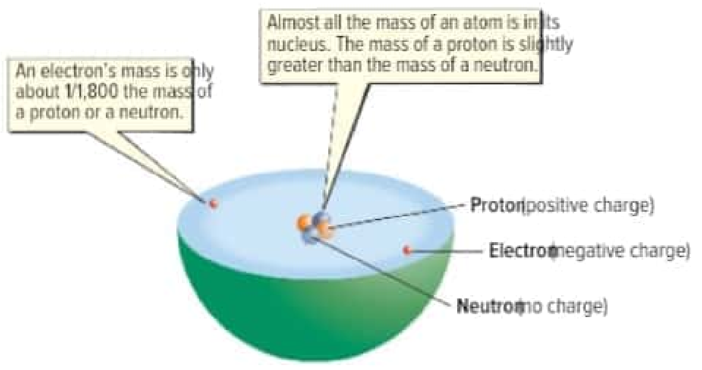
Ask: Why might proton have originated from a word that means "first"? *The number of protons in a nucleus identifies the type of atom. This might be why it is considered "first" among atomic particles.*

Guiding Questions

OL Why does a nucleus always have a positive charge?	*The nucleus has a positive charge because protons have positive charges and neutrons have no charge.*
OL Where are protons, neutrons, and electrons located in an atom?	*Protons and neutrons are in the nucleus. Electrons are in an electron cloud surrounding the nucleus.*

Visual Literacy: Parts of an Atom

Have students examine Figure 12 to learn about the parts of an atom.



Ask: How many protons and how many electrons does this atom have? *2 protons and 2 electrons*

Ask: How does an electron and a neutron differ in size? *An electron is about 1/1,800 the size of a neutron.*

Electrons

Remind students about the old plum pudding model that they learned about the beginning of the lesson. Explain that scientists have refined atomic models over time as they learned more about atoms and their particles. Today, we know that the structure of an atom looks like the diagrams in **Figures 12** and **13.** Have them read the first two paragraphs to learn more about electrons. Then use the following scaffolded questions to informally assess their comprehension.

Guiding Questions

AL What does an electron cloud mostly contain?	*empty space*
OL In an atom, which electrons have the highest amount of energy?	*the ones that are farthest from the nucleus*
BL As you will read later in the lesson, atoms can lose electrons. Predict which electron in Figure 13 will be lost first—one closest to the nucleus or one farthest from the nucleus.	*The electron farthest from the nucleus will be lost first, because it is less attracted to the nucleus.*

Students should be reminded that the electron cloud is not the same as a cloud in the sky. Nor is there a cloud-like material in which the electrons travel. The electron cloud is made up of electrons traveling in empty space.

Differentiated Instruction

Modeling the Atom Students at all levels may struggle with understanding the model of the atom shown in **Figure 13** simply because it is not in motion. As a static figure, it do[es not] convey the sense of movement within the atomic structu[re]. Find an open space where students can move around fre[ely]. Call out the number of protons, neutrons, and electrons i[n] different atoms (for example, carbon has six protons, six neutrons, and six electrons) and ask students to demonst[rate] each atom's structure according to their designations.

AL Designate AL students as protons. Their primarily rol[e] will be to observe and maintain the correct number of pr[otons] and neutrons in the nucleus.

BL Designate BL students as electrons. They will need t[o] move around within electron clouds rapidly without leavi[ng a] general circular path. The innermost circle can have only two students, while all other concentric circles can have a maximum of eight.

Teacher Toolbo[x]

Reading Strategy

Mind Mapping Have pairs of students create a mind ma[p] of the model of the atom. Instruct them to name the particles in an atom as the main idea and create branch[es] that identify where the particles are located and how th[ey] function inside an atom.

Cultural Diversity

A Model from Many Nations The development of the electron cloud model spans different decades and cult[ures]. Scientists from Great Britain, Denmark, and other count[ries] all made contributions to the model that we currently us[e] today. The theory developed as scientists learned more [and] more about atoms.

Figure 13 Electrons farther from the nucleus have more energy.

Math Skill

Use Scientific Notation
Scientists write very large and very small values using scientific notation. A gram of carbon has about 50,000,000,000,000,000,000 atoms. Express this in scientific notation.

1. Move the decimal until one nonzero digit remains on the left: 5.0000000000000000000
2. Count the places you moved. Here it is 19 left.
3. Show that number as a power of 10. The exponent is negative if the decimal moves right and positive if it moves left. Answer: 5×10^{19}
4. Reverse the process to change scientific notation back to a whole number.

Practice
The diameter of a carbon atom is 2.2×10^{-8} cm. Write this as a whole number.

An Electron Cloud Drawings of an atom, such as the one in **Figure 13**, often show electrons circling the nucleus like planets orbiting the Sun. Scientists have conducted experiments that show the movement of electrons is more complex than this. The modern idea of an atom is called the electron cloud model. **electron cloud** *the region surrounding an atom's nucleus where one or more electrons are most likely to be found.* It is important to understand that an electron is not a cloud of charge. An electron is one tiny particle. An electron cloud is mostly empty space. At any moment in time, electrons are located at specific points within that area.

Electron Energy You have read that electrons are constantly moving around the nucleus in a region called the electron cloud. However, some electrons are closer to the nucleus than others. Electrons occupy certain areas around the nucleus according to their energy, as shown in **Figure 13**. Electrons close to the nucleus are strongly attracted to it and have less energy. Electrons farther from the nucleus are less attracted to it and have more energy.

The Size of Atoms

It might be difficult to visualize an atom, but every solid, liquid, and gas is made of millions and millions of atoms. Your body, your desk, and the air you breathe are all made of tiny atoms. To understand how small an atom is, look at **Figure 14**. Suppose you could increase the size of everything around you. If you could multiply the width of an atom by 100 million (10^8), it would be the size of an orange. An orange would then increase to the size of Earth!

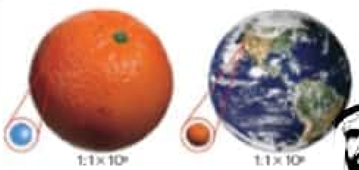


Figure 14 If an orange were the size of Earth, then an atom would be the size of an orange.

Differences in Atoms

In some ways atoms are alike. Each has a positively charged nucleus surrounded by a negatively charged electron cloud. But atoms can differ from each other in several ways. Atoms can have different numbers of protons, neutrons, or electrons.

Describe List the main ideas from this section in the lines below.

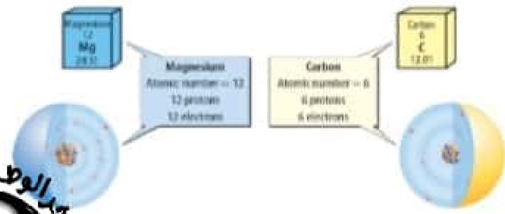
Protons and Atomic Number

Look at the periodic table in the back of this book. In each block, the number under the element name shows how many protons each atom of the element has. For example, each oxygen atom has eight protons. The **atomic number** *the number of protons in the nucleus of an atom of an element.* If there are 12 protons in the nucleus of an atom, that element's atomic number is 12. Examine **Figure 15**. Notice that the atomic number of magnesium is the whole number above its symbol. The atomic number of carbon is 6. This means that each carbon atom has 6 protons.

Key Concept Check
5. How is the atomic number related to the number of protons in an atom?

Every element in the periodic table has a different atomic number. You can identify an element if you know either its atomic number or the number of protons its atoms have. If an atom has a different number of protons, it is a different element.

Figure 15 An atomic number is the number of protons in each atom of the element.



The Size of Atoms

Have students read the paragraph and study the comparison shown in **Figure 14**. Understanding scale may be difficult for some students. To help them comprehend this concept, you may wish to have them multiply the size of everyday objects by 100 million. For example, the length of an average car is between 4.88 m and 5 m. Multiply that times 100 million and you would have a car that is about 500 million meters long. Ask the following question to guide your students' comprehension.

Guiding Questions

OL By what amount would you have to multiply the size of an atom to make it as large as an orange?	*100 million or 10^8*
BL Do you think all atoms are the exact same size? Why or why not?	*Answers may vary. Sample answer: No, because different kinds of atoms have different numbers of particles, so they are different sizes.*

Math Skill

Use Scientific Notation

Explain that scientific notation makes it easier to manipulate very large and very small values. Because converting to and from scientific notation is a skill, it is important that students follow and practice the steps.

Practice

Have students solve the practice question. Then ask a volunteer to write the steps he or she used to find the answer on chart paper or the board. *0.000000022 cm*

Differences in Atoms

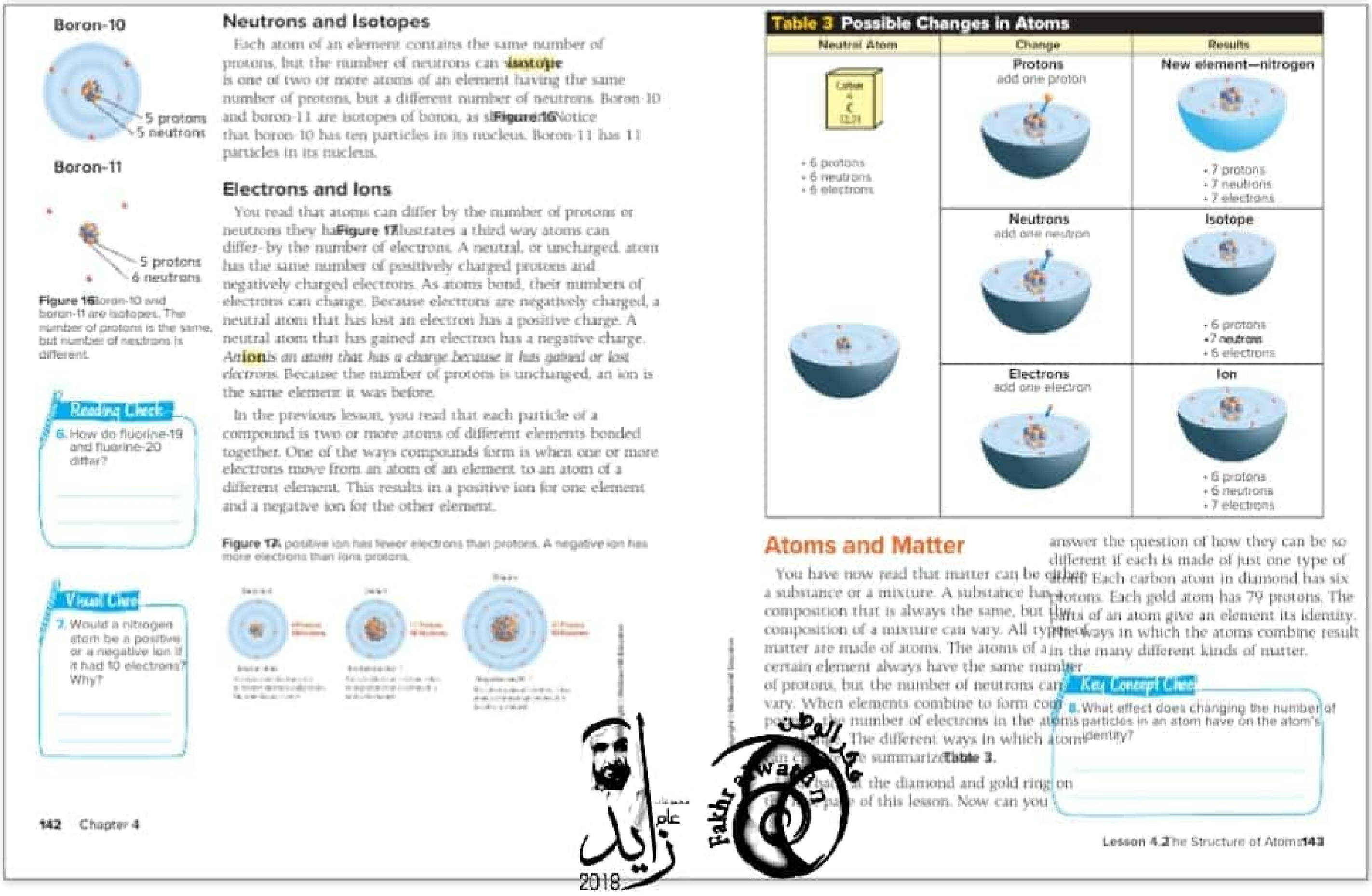
Remind students that, although atoms have the same basic structure and the same kinds of particles, the difference in the number and combinations of these particles result in differences among different kinds of atoms. Have students read the paragraph.

Protons and Atomic Number

Have students read the paragraphs and study **Figure 15**. Also ask them to turn to the periodic table at the back of their textbooks to find the atomic numbers of magnesium, carbon, and other elements. Then ask these guiding questions.

Guiding Questions

OL How is the atomic number related to the number of protons in an atom?	*The atomic number is the same as the number of protons in the atom.*
BL If you know the number of protons in a neutral atom, what else do you know?	*You know the number of electrons. It will always be the same as the number of protons for an atom that is neutral.*



Boron-10

5 protons
5 neutrons

Boron-11

5 protons
6 neutrons

Figure 16 Boron-10 and boron-11 are isotopes. The number of protons is the same, but number of neutrons is different.

Reading Check

6. How do fluorine-19 and fluorine-20 differ?

Visual Check

7. Would a nitrogen atom be a positive or a negative ion if it had 10 electrons? Why?

Neutrons and Isotopes

Each atom of an element contains the same number of protons, but the number of neutrons can vary. An isotope is one of two or more atoms of an element having the same number of protons, but a different number of neutrons. Boron-10 and boron-11 are isotopes of boron, as shown in Figure 16. Notice that boron-10 has ten particles in its nucleus. Boron-11 has 11 particles in its nucleus.

Electrons and Ions

You read that atoms can differ by the number of protons or neutrons they have. Figure 17 illustrates a third way atoms can differ–by the number of electrons. A neutral, or uncharged, atom has the same number of positively charged protons and negatively charged electrons. As atoms bond, their numbers of electrons can change. Because electrons are negatively charged, a neutral atom that has lost an electron has a positive charge. A neutral atom that has gained an electron has a negative charge. An ion is an atom that has a charge because it has gained or lost electrons. Because the number of protons is unchanged, an ion is the same element it was before.

In the previous lesson, you read that each particle of a compound is two or more atoms of different elements bonded together. One of the ways compounds form is when one or more electrons move from an atom of an element to an atom of a different element. This results in a positive ion for one element and a negative ion for the other element.

Figure 17 A positive ion has fewer electrons than protons. A negative ion has more electrons than ions protons.

Table 3 Possible Changes in Atoms

Neutral Atom	Change	Results
Carbon 6 C 12.01; • 6 protons • 6 neutrons • 6 electrons	Protons: add one proton	New element—nitrogen: • 7 protons • 7 neutrons • 7 electrons
	Neutrons: add one neutron	Isotope: • 6 protons • 7 neutrons • 6 electrons
	Electrons: add one electron	Ion: • 6 protons • 6 neutrons • 7 electrons

Atoms and Matter

You have now read that matter can be either a substance or a mixture. A substance has a composition that is always the same, but the composition of a mixture can vary. All types of matter are made of atoms. The atoms of a certain element always have the same number of protons, but the number of neutrons can vary. When elements combine to form compounds, the number of electrons in the atoms can change. The different ways in which atoms ... are summarized in Table 3.

... the diamond and gold ring on ... of this lesson. Now can you answer the question of how they can be so different if each is made of just one type of atom? Each carbon atom in diamond has six protons. Each gold atom has 79 protons. The protons of an atom give an element its identity. The ways in which the atoms combine result in the many different kinds of matter.

Key Concept Check

8. What effect does changing the number of particles in an atom have on the atom's identity?

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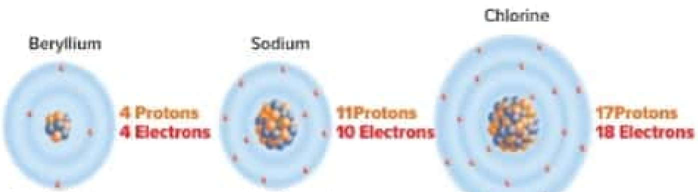
Lesson 4.2 The Structure of Atoms 143

Visual Literacy: Ions

Have students study the diagrams of Figure 17. Then have them turn to the periodic tables in their textbooks to answer the following question.



Neutral atom
A neutral atom has the same number of electrons and protons. The atom has

Positive ion (Na+)
If an atom loses an electron, it has more protons than electrons. It is positively charged.

Negative ion (Cl-)
If an atom gains an electron, it has more electrons than protons. It is negatively

Ask: **Would a nitrogen atom be a positive or a negative ion if it had 10 electrons? Why?** *It would be a negative ion because, according to the periodic table, a nitrogen atom has 7 protons. An atom must have the same number of electrons as protons to be neutral. Therefore nitrogen has 10 electrons. Three extra electrons would give it a negative charge.*

Atoms and Matter

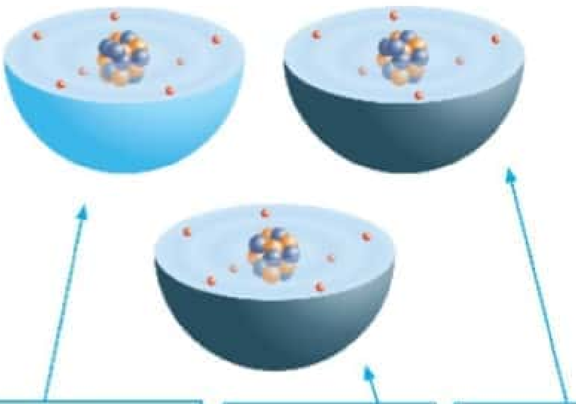
After learning all the information about the structure of atoms, students will need time to organize, summarize, and reflect upon what they have learned. Use the following questions to help them put all the pieces together.

Guiding Questions

AL What is the difference between an ion and an isotope?	*An ion is a charged atom that has gained or lost electrons. An isotope is one of two or more atoms of an element with different numbers of neutrons.*
OL What effect does changing the number of particles in an atom have on the atom's identity?	*Changing the number of protons produces a different type of atom, but the identity of an atom stays the same if the number of neutrons or electrons is different.*
BL With all the ways that atoms can change, what is true of all atoms?	*All atoms have a nucleus, contain at least one proton, and contain electrons within the electron cloud.*

Visual Literacy: Possible Changes in Atoms

Have students locate the periodic table representation for carbon at the top of **Table 3**. Ask them to identity the atomic number and the number of protons in carbon (6). Then have them compare the different examples of atoms shown in the table. Ask the following questions to assess their understanding.



Ask: How does adding a proton change the carbon atom? *It changes the identity of the atom. It becomes a nitrogen atom instead.*

Ask: How does adding an electron change the carbon atom? *It becomes a carbon ion.*

Ask: How does adding a neutron change the carbon atom? *It becomes a carbon isotope.*

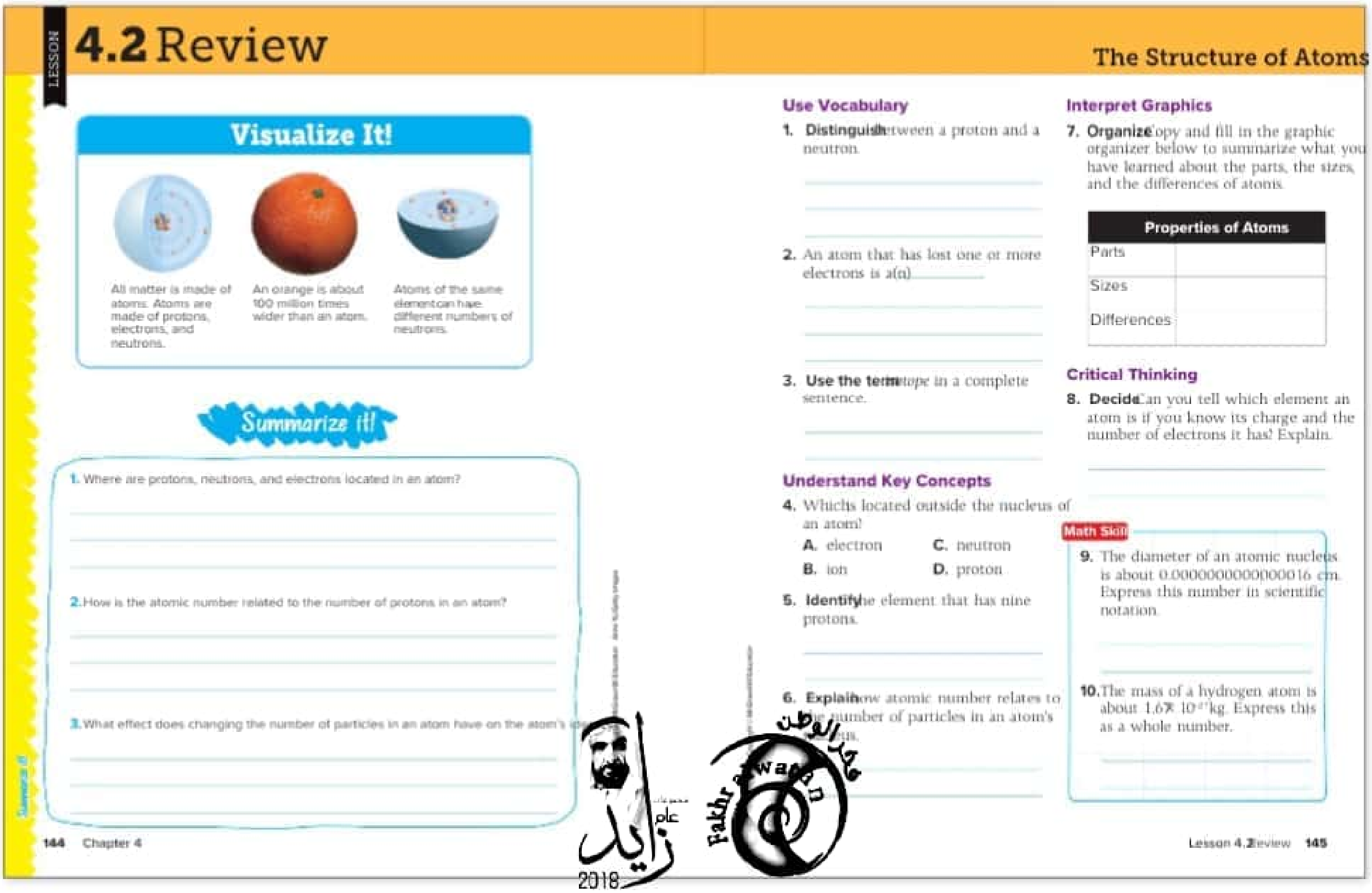
Teacher Toolb

Fun Fact

Seeing an Atom The twentieth century was marked by th fascination with the structure and later the power of th atom, but it wasn't until the invention of the scanning tunneling microscope in 1981 and the atomic force microscope in 1986 that individual atoms could be see manipulated. Today, advanced versions of these microscopes allow for even more detailed views and greater control of the atomic world.

Reading Strategy

Five Minute Theater Have groups of students write five-minute plays telling the story of an atom and some the changes it can undergo. Each student in the group play a different role, either as protons, electrons, or neutrons. Encourage them to be creative and incorpor what they have learned about the structure of the aton


LESSON **4.2 Review**

The Structure of Atoms

Visualize It!

All matter is made of atoms. Atoms are made of protons, electrons, and neutrons.

An orange is about 100 million times wider than an atom.

Atoms of the same element can have different numbers of neutrons.

Summarize It!

1. Where are protons, neutrons, and electrons located in an atom?

2. How is the atomic number related to the number of protons in an atom?

3. What effect does changing the number of particles in an atom have on the atom's id

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Use Vocabulary

1. **Distinguish** between a proton and a neutron.

2. An atom that has lost one or more electrons is a(n) ____.

3. **Use the term** *isotope* in a complete sentence.

Understand Key Concepts

4. Which is located outside the nucleus of an atom?
A. electron C. neutron
B. ion D. proton

5. **Identify** the element that has nine protons.

6. **Explain** how atomic number relates to the number of particles in an atom's ...

Interpret Graphics

7. **Organize** Copy and fill in the graphic organizer below to summarize what you have learned about the parts, the sizes, and the differences of atoms.

Properties of Atoms	
Parts	
Sizes	
Differences	

Critical Thinking

8. **Decide** Can you tell which element an atom is if you know its charge and the number of electrons it has? Explain.

Math Skills

9. The diameter of an atomic nucleus is about 0.0000000000000016 cm. Express this number in scientific notation.

10. The mass of a hydrogen atom is about 1.67×10^{-27} kg. Express this as a whole number.

Lesson 4.2 Review 145

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Use Vocabulary

1. A proton has a positive charge. A neutron has no charge.

2. ion

3. Sample answer: Carbon-13 is an isotope of carbon which has 7 neutrons.

Understand Key Concepts

4. A. electron

5. fluorine

6. The atomic number is the number of protons in an atom's nucleus.

Interpret Graphics

7.

Properties of Atoms	
Parts	Protons and neutrons are in the nucleus, and electrons are in the electron cloud.
Size	A nucleus is about a trillion times smaller than the tip of a pencil.
Difference	An atom which loses or gains a proton is a different element. An atom which loses or gains a neutron is an isotope of the original atom. An atom which loses or gains an electron is an ion.

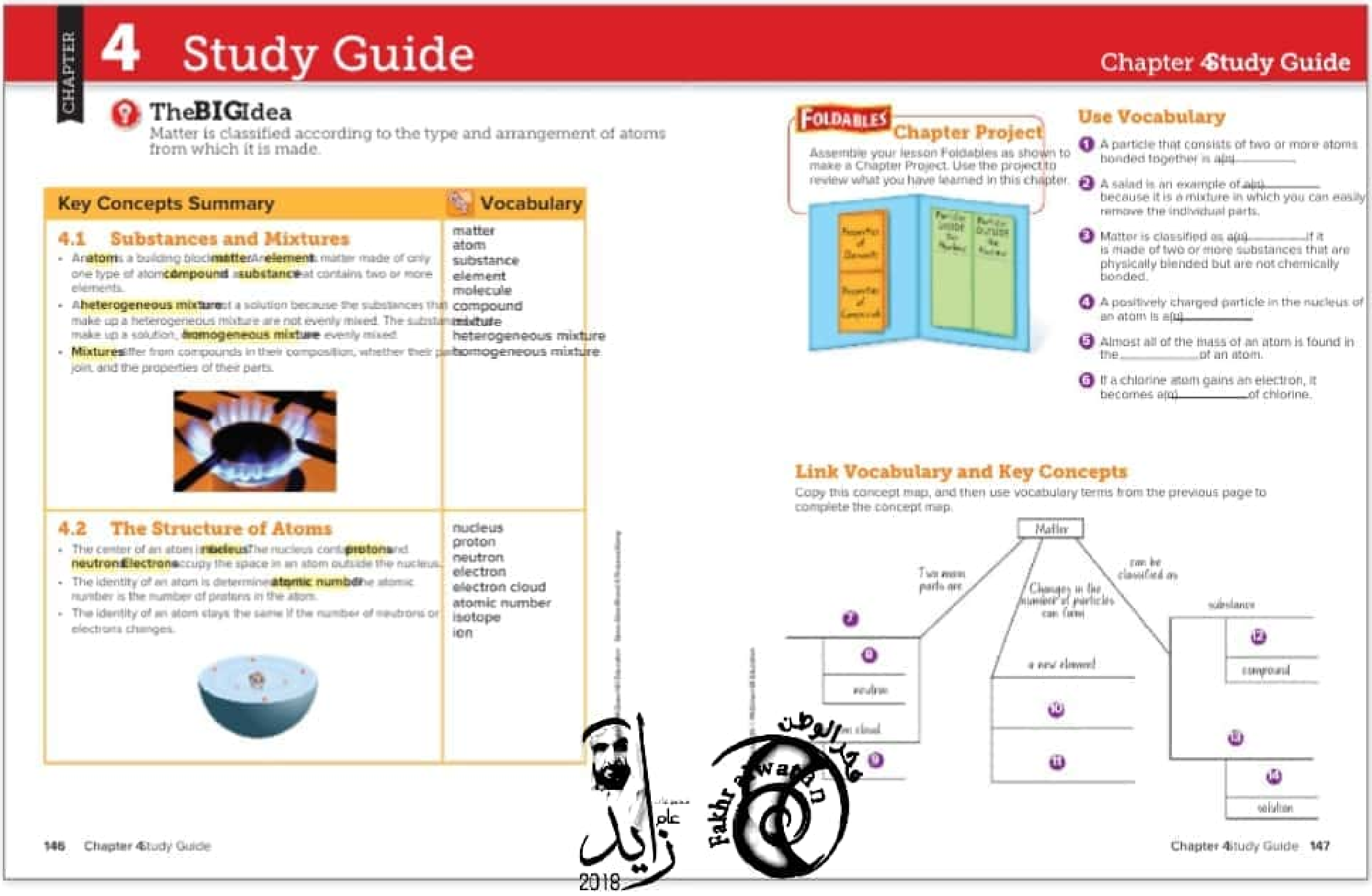
Critical Thinking

8. Yes. For a positive charge, you add the number of the charge to the number of electrons to get the atomic number. For a negative charge, you subtract the number of the charge from the number of electrons to get the atomic number. The atomic number identifies the element.

Math Skills

9. 1.6×10^{15} cm

10. 0.00000000000000000000000000167 kg



CHAPTER 4 Study Guide

Chapter 4 Study Guide

TheBIGIdea
Matter is classified according to the type and arrangement of atoms from which it is made.

Key Concepts Summary	Vocabulary
4.1 Substances and Mixtures • An **atom** is a building block of **matter**. An **element** is matter made of only one type of atom. A **compound** is a **substance** that contains two or more elements. • A **heterogeneous mixture** is not a solution because the substances that make up a heterogeneous mixture are not evenly mixed. The substances that make up a solution, a **homogeneous mixture**, are evenly mixed. • **Mixtures** differ from compounds in their composition, whether their parts join, and the properties of their parts.	matter atom substance element molecule compound mixture heterogeneous mixture homogeneous mixture
4.2 The Structure of Atoms • The center of an atom is the **nucleus**. The nucleus contains **protons** and **neutrons**. **Electrons** occupy the space in an atom outside the nucleus. • The identity of an atom is determined by its **atomic number**. The atomic number is the number of protons in the atom. • The identity of an atom stays the same if the number of neutrons or electrons changes.	nucleus proton neutron electron electron cloud atomic number isotope ion

FOLDABLES Chapter Project
Assemble your lesson Foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter.

Use Vocabulary

1. A particle that consists of two or more atoms bonded together is a(n) ________.
2. A salad is an example of a(n) ________ because it is a mixture in which you can easily remove the individual parts.
3. Matter is classified as a(n) ________ if it is made of two or more substances that are physically blended but are not chemically bonded.
4. A positively charged particle in the nucleus of an atom is a(n) ________.
5. Almost all of the mass of an atom is found in the ________ of an atom.
6. If a chlorine atom gains an electron, it becomes a(n) ________ of chlorine.

Link Vocabulary and Key Concepts
Copy this concept map, and then use vocabulary terms from the previous page to complete the concept map.

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Chapter 4 Study Guide 147

Key Concepts Summary

Study Strategy: Check Answers to Key Concept Questions

Teach students to focus on the areas where they lack understanding and to spend less time on concepts they have mastered.

1. Write the Key Concept questions from the start of each lesson on chart paper or the board.
2. Ask students to answer each question in their science journal.
3. Instruct students to make note of the questions that they had a difficult time answering. Then have them compare their answers to the Key Concepts Summary in the Chapter Study Guide. Tell them to write a check beside any answers that were correct and to circle any answers that were inaccurate or incomplete.
4. Have students look back through the chapter to locate any information relevant to the answers they circled. Have them use this information to rewrite their answers.

Example:

An ion is a charged atom that has gained or lost electrons ✓

An isotope is one of two atoms of an element that have a different number of protons

Vocabulary

Study Strategy: Create Vocabulary Trading Cards

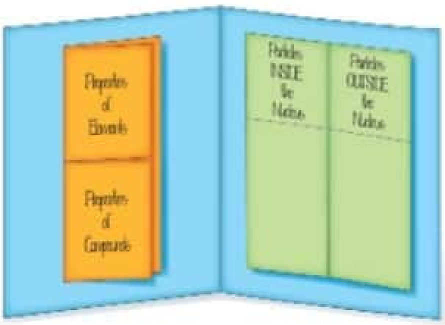
Have students make trading cards using the vocabulary words from the chapter.

1. Ask students to write the vocabulary words on the front of index cards. Students may also wish to include a diagram or an illustration that represents each term on the front of their cards.
2. Ask them to write the definition for each term in their own words on the back of the cards. Connecting vocabulary words to students' own language promotes understanding more effectively than pure memorization.
3. After students complete their cards, have them share and exchange them with each other.

Example:

Element	something that is pure and is made up of only one kind of atom

FOLDABLES®



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables.

Use Vocabulary

1. molecule
2. heterogeneous mixture
3. mixture
4. proton
5. nucleus
6. ion

Link Vocabulary and Key Concepts

7. nucleus
8. proton
9. electron
10–11. ion, isotope (in any order)
12. element
13. mixture
14. heterogeneous mixture

Teacher Notes

CHAPTER 4 Review

Chapter Review

Understand Key Concepts

1. Which is a substance?
   - A. fruit salad
   - B. granola cereal
   - C. spaghetti
   - D. table salt
2. Which is the best model for a homogeneous mixture?
   - A.

   - B.

   - C.

   - D.

3. Which is a property of all atoms?
   - A. more electrons than protons
   - B. a nucleus with a positive charge
   - C. a positively charged electron cloud
   - D. same number of protons as neutrons
4. Which is another name for a solution?
   - A. element
   - B. compound
   - C. heterogeneous mixture
   - D. homogeneous mixture
5. Which would you most likely be able to separate into its parts by filtering?
   - A. heterogeneous mixture of two liquids
   - B. heterogeneous mixture of two solids
   - C. homogeneous mixture of two liquids
   - D. homogeneous mixture of two solids
6. Where is almost all the mass of an atom located?
   - A. in the electrons
   - B. in the neutrons
   - C. in the nucleus
   - D. in the protons
7. Which best describes an electron cloud?
   - A. an area of charged particles with a fixed boundary
   - B. electrons on a fixed path around the nucleus
   - C. mostly empty space with tiny charged particles in it
   - D. a solid mass of charge around the nucleus
8. Which is true about carbon-12 compared with carbon-13?
   - A. Carbon-12 has more neutrons.
   - B. Carbon-12 has more protons.
   - C. Carbon-13 has more neutrons.
   - D. Carbon-13 has more protons.
9. Look at the periodic table block below for potassium. How many electrons does an uncharged atom of potassium have?

Potassium
19
K
39.10

   - A. 19
   - B. 20
   - C. 39
   - D. 40

148 Chapter 4 Review

Critical Thinking

10. **Classify** Look at the illustration below. Is this a model of a substance or a mixture? How do you know?

11. **Deduce** Each atom of protium has one proton, no neutrons, and one electron. Each atom of deuterium has one proton, two neutrons, and one electron. Are these the same or different elements? Why?
12. **Decide** Suppose you mix several liquids in a jar. After a few minutes, the liquids form layers. Is this a homogeneous mixture or a heterogeneous mixture? Why?
13. **Describe** a method for separating a mixture of salt water.
14. **Generalize** Consider the substances O_3, N_2, H_2, CH_4, H_2O, KCl, and O_2. Is it possible to tell just from the symbols and the numbers which are elements and which are compounds? Explain.
15. **Suggest** how you can define an electron cloud differently from the chapter.
16. **Analyze** A substance has an atomic number of 80. How many protons and electrons do atoms of the substance have? What is the substance?

Writing in Science

17. **Write** a paragraph in which you explain the modern atomic model to an adult who has never heard of it before. Include two questions he or she might ask, and write answers to the questions.

The BIG Idea

18. Explain how compounds, elements, heterogeneous mixtures, homogeneous mixtures, matter, and substances are related.

Math Skill

Use Scientific Notation

19. The mass of one carbon atom is 0.00000000000000000000001994 g. Express this number in scientific notation.
20. The mass of an electron is about 10^{-31} kg. Write this as a whole number.
21. In 2 L of hydrogen gas, there are about 54,000,000,000,000,000,000,000 hydrogen atoms. Express the number of atoms using scientific notation.
22. Quantities in chemistry are often described by the unit mole. One mole is defined as about 6×10^{23} particles. Write this as a whole number.
23. The mass of hydrogen-3, tritium, is about 10^{-27} kg. Write this as a whole number.

Chapter 4 Review 149

Understand Key Concepts

1. **D.** table salt
2. **A.**
3. **B.** a nucleus with a positive charge
4. **D.** homogeneous mixture
5. **B.** heterogeneous mixture of two liquids
6. **C.** in the nucleus
7. **C.** mostly empty space with tiny charged particles in it
8. **C.** Carbon-13 has more neutrons.
9. **A.** 19

Critical Thinking

10. The drawing is a model of a substance, specifically, a compound. You can tell because the combination of atoms is always the same.
11. They are the same element (hydrogen) because they have the same number of protons. Protium and deutrerium are isotopes of hydrogen—the number of neutrons they have varies.
12. It is a heterogeneous mixture because it contains substances that are not evenly mixed.
13. You could heat the water until it boils. The water would evaporate, leaving behind the salt.
14. Yes; an element has just one type of atom, although the molecule may contain more than one atom of that element. A compound has more than one type of atom. H_2 and O_2 are the only elements listed because they have only one type of atom.
15. Sample answer: An electron cloud is the area of negative charge around a nucleus.
16. Atoms of the substance have 80 protons and 80 electrons. The substance is mercury.

Writing in Science

17 Paragraphs should describe a positively charged nucleus surrounded by an electron cloud. Protons and neutrons are in the nucleus, and electrons are in the electron cloud. Sample questions and answers: Where are the electrons located? *The electrons are located in the empty space around the nucleus. The space is usually described as a cloud since we cannot be sure exactly where each electron is at a given moment.* Which particles have a positive charge and which particles have a negative charge? *Protons have a positive charge, electrons have a negative charge, and neutrons are neutral.*

The BIG Idea

18 Matter is classified as either a substance or a mixture. Two types of substances are elements and compounds. Two types of mixtures are heterogeneous mixtures and homogeneous mixtures.

19 The classification of matter depends on the number and arrangement of atoms. Substances are elements, which are made of one type of atom, or compounds, which are made of two or more atoms that have bonded together. On the other hand, mixtures are made of two or more substances that have not chemically bonded. The composition of a mixture may vary.

Math Skill

Use Scientific Notation

20 1.994×10^{-23} g

21 0.000000000000000000000000000000911 kg

22 5.4×10^{22} atoms

23 602,200,000,000,000,000,000,000 particles

24 0.0000000000000000000000000501 kg

OL On Level AL Approaching Level BL Beyond Level

Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice

Use the figure below to answer questions 1 and 2.

1 How many atoms are in the particle?
- A 1
- B 2
- C 3
- D 5

2 Which kind of matter might contain only this type of particle?
- A a compound
- B an element
- C a heterogeneous mixture
- D a homogeneous mixture

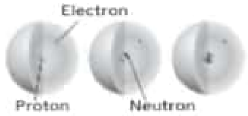
3 Which class of matter is the least evenly mixed?
- A compounds
- B heterogeneous mixtures
- C homogeneous mixtures
- D solutions

4 Which correctly describes a compound but not a mixture?
- A All the atoms are of the same element.
- B All the molecules have at least two atoms.
- C The combination of substances never changes.
- D The substances can be separated without breaking bonds.

5 A girl pours a spoonful of sugar into a glass of warm water. She stirs the water until the sugar disappears. When she tastes the water, she notices that it is now sweet. Which describes the kind of matter in the glass?
- A a compound
- B an element
- C a solution
- D a substance

6 How could you separate a mixture of stone and wooden beads that are all the same size?
- A Add water to the mixture and skim off the wooden beads, which float.
- B Heat the mixture until the stone beads melt.
- C Strain the mixture to separate out the stone beads.
- D Use a magnet to pull out the wooden beads.

Use the figure below to answer question 7.



7 The figure shows models of three different atoms. What can you conclude about the three models shown in the figure?
- A They all show positive ions.
- B They all show negative ions.
- C They all show the same element.
- D They all show the same isotope.

8 What is the atomic number of an atom that has 2 electrons, 3 protons, and 4 neutrons?
- A 2
- B 3
- C 4
- D 7

Use the table below to answer questions 9 and 10.

	Number of Protons	Number of Neutrons	Number of Electrons
A	8	8	8
B	8	8	10
C	8	9	8
D	9	10	9

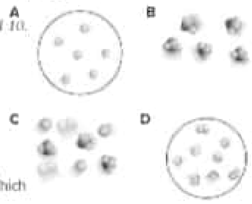
9 The table shows the numbers of protons, neutrons, and electrons for four atoms. Which atom has a negative charge?
- A A
- B B
- C C
- D D

10 Which of the atoms is a different element than the others?
- A A
- B B
- C C
- D D

Constructed Response

11 How do protons, electrons, and neutrons differ in charge and location in the atom?

Use the figures below to answer questions 12 and 13.



12 Classify each model A–D as either an element, a compound, or a mixture. Explain your reasoning for each answer.

13 Imagine that samples A and D were reacted and formed a compound. Then imagine that the same samples were combined to form a mixture. How would the two combinations differ?

14 Suppose a neutral atom has 5 protons, 5 neutrons, and 5 electrons. List the number of protons, electrons, and neutrons for the following.
- a. a positive ion of the same element
- b. a negative ion of the same element
- c. a neutral isotope of the same element

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Go to Lesson...	1	1	1	1	1	1	2	2	2	2	1	1	2	2

Multiple Choice

1 **D—Correct.** A is the number of molecules, B is the number of different elements, C is the number of atoms of one type of element in the molecule.

2 **A—Correct.** B and C would have to show more than one type of particle, D would have to have atoms of all the same type.

3 **B—Correct.** A has molecules of all the same type and is therefore evenly mixed. C and D describe the same type of evenly mixed mixture.

4 **C—Correct.** A describes an element, B could describe both compounds and mixtures, and D describes only mixtures.

5 **C—Correct.** A would not involve parts of the mixture having the same property or sweetness before and after combining, B would involve only one kind of matter, and D describes elements and compounds but not mixtures.

6 **A—Correct.** B would not work because the wooden beads would be destroyed by temperatures high enough to melt stone. C would work only on beads of different sizes. D would not work because stone and wood are not magnetic materials.

7 **C—Correct.** A and B are incorrect because none of the models are ions, they all have just one proton and one electron, which means the atom does not have a charge. D is incorrect because the models show different isotopes of the same element, not the same isotope.

8 **B—Correct.** A can be used to determine charge, C can be used to determine isotope number, and D is the mass number.

9 **B—Correct.** A, C, and D have the same numbers of protons and electrons and are thus neutral.

10 **D—Correct.** A, B, and C have the same number of protons and different numbers of neutrons, which makes them isotopes of one another.

Constructed Response

11 Protons have positive charges and are located in the nucleus. Electrons have negative charges and are located in a cloud around the nucleus. Neutrons have no charge and are located in the nucleus.

12 Samples A and D are elements because their particles are made up of one kind of atom. Sample B is a compound because its particles are all the same but they are made up of more than one kind of atom. Sample C is a mixture because its particles are different.

13 Sample answer: The model for the compound would show that all the particles are the same. Each molecule would have at least one of each type of atom. The model for the mixture would show the original particles randomly mixed. No new combinations of atoms (bonds) would be shown.

14 A positive ion would have 5 protons, 5 neutrons, and 4 electrons. A negative ion would have 5 protons, 5 neutrons, and 6 electrons. A neutral isotope could have 5 protons, 5 electrons and X neutrons, where 6 X

Answer Key

Question	Answer
1	D
2	A
3	B
4	C
5	C
6	A
7	C
8	B
9	B
10	D
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answe