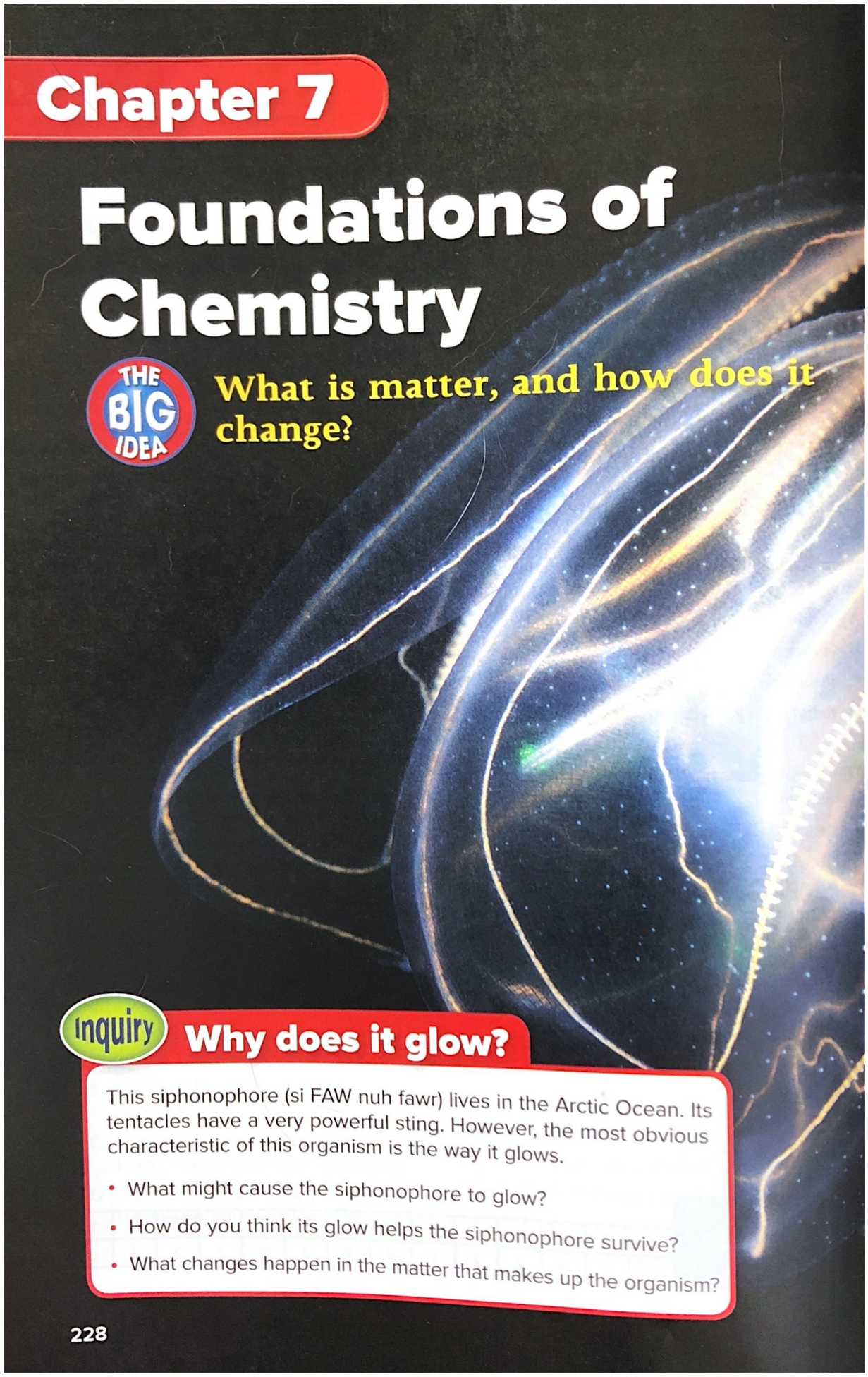
Chapter 7

Foundations of Chemistry

THE BIG IDEA

What is matter, and how does it change?



Inquiry

Why does it glow?

This siphonophore (si FAW nuh fawr) lives in the Arctic Ocean. Its tentacles have a very powerful sting. However, the most obvious characteristic of this organism is the way it glows.

- What might cause the siphonophore to glow?
- How do you think its glow helps the siphonophore survive?
- What changes happen in the matter that makes up the organism?

Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. The atoms in all objects are the same.
2. You cannot always tell by an object's appearance whether it is made of more than one type of atom.
3. The weight of a material never changes, regardless of where it is.
4. Boiling is one method used to separate parts of a mixture.
5. Heating a material decreases the energy of its particles.
6. When you stir sugar into water, the sugar and water evenly mix.
7. When wood burns, new materials form.
8. Temperature can affect the rate at which chemical changes occur.

Lesson 1

Classifying Matter

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- What is a substance?
- How do atoms of different elements differ?
- How do mixtures differ from substances?
- How can you classify matter?

Vocabulary

matter p. 231
atom p. 231
substance p. 233
element p. 233
compound p. 234
mixture p. 235
heterogeneous mixture p. 235
homogeneous mixture p. 235
dissolve p. 235

Multilingual eGlossary

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Science Video
What's Science Got to do With It?

Inquiry Making Green?

You probably have mixed paints together. Maybe you wanted green paint and had only yellow paint and blue paint. Perhaps you watched an artist mixing several tints get the color he or she needed. In all these instances, the final color came from mixing colors together and not from changing the color of a paint.

Launch Lab

15 minutes

How do you classify matter?

An object made of paper bound together might be classified as a book. Pointed metal objects might be classified as nails or needles. How can you classify an item based on its description?

1. Read and complete a lab safety form.
2. Place the **objects** on a table. Discuss how you might separate the objects into groups with these characteristics:
   a. Every object is the same and has only one part.
   b. Every object is the same but is made of more than one part.
   c. Individual objects are different. Some have one part, and others have more than one part.
3. Identify the objects that meet the requirements for group *a*, and record them in your Science Journal. Repeat with groups *b* and *c*. Any object can be in more than one group.

Think About This

1. Does any object from the bag belong in all three of the groups (*a*, *b*, and *c*)? Explain.
2. What objects in your classroom would fit into group *b*?
3. **Key Concept** What descriptions would you use to classify items around you?

Understanding Matter

Have you ever seen a rock like the one in **Figure 1?** Why are different parts of the rock different in color? Why might some parts of the rock feel harder than other parts? The parts of the rock look and feel different because they are made of different types of matter. **Matter** *is anything that has mass and takes up space.* If you look around, you will see many types of matter. If you are in a classroom, you might see things made of metal, wood, or plastic. If you go to a park, you might see trees, soil, or water in a pond. If you look up at the sky, you might see clouds and the Sun. All of these things are made of matter.

Everything you can see is matter. However, some things you cannot see also are matter. Air, for example, is matter because it has mass and takes up space. Sound and light are not matter. Forces and energy also are not matter. To decide whether something is matter, ask yourself if it has mass and takes up space.

An **atom** *is a small particle that is a building block of matter.* In this lesson, you will explore the parts of an atom and read how atoms can differ. You will also read how different arrangements of atoms make up the many types of matter.

WORD ORIGIN

matter
from Latin *materia*, meaning "material, stuff"

Figure 1 You can see different types of matter in this rock.

(t)Hutchings Photography/Digital Light Source, (b)©Doug Sherman/Geofile

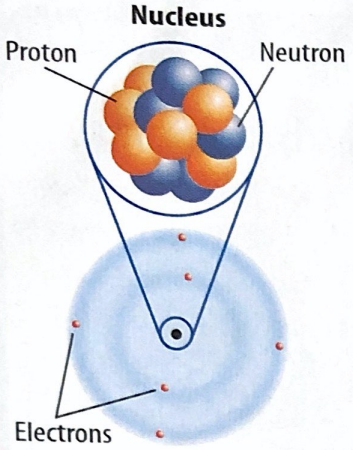


Figure 2 An atom has electrons moving in an area outside a nucleus. Protons and neutrons make up the nucleus.

Personal Tutor

Atoms

To understand why there are so many types of matter, it helps if you first learn about the parts of an atom. Look at the diagram of an atom in **Figure 2.** At the center of an atom is a nucleus. Protons, which have a positive charge, and neutrons, which have a neutral charge, make up the nucleus. Negatively charged particles, or electrons, move quickly throughout an area around the nucleus called the electron cloud.

Reading Check What are the parts of an atom?

Not all atoms have the same number of protons, neutrons, and electrons. Atoms that have different numbers of protons differ in their properties. You will read more about the differences in atoms on the next page.

An atom is almost too small to imagine. Think about how thin a human hair is. The diameter of a human hair is about a million times greater than the diameter of an atom. In addition, an atom is about 10,000 times wider than its nucleus! Even though atoms are so tiny, they determine the properties of the matter they compose.

MiniLab

20 minutes

How can you model an atom?

How can you model an atom out of its three basic parts?

1. Read and complete a lab safety form.
2. Twist the ends of a piece of **florist wire** together to form a ring. Attach two **wires** across the ring to form an *X*.
3. Use **double-sided tape** to join the **large pom-poms** (protons and neutrons), forming a nucleus. Hang the nucleus from the center of the *X* with **fishing line.**
4. Use fishing line to suspend each **small pom-pom** (electron) from the ring so they surround the nucleus.
5. Suspend your model as instructed by your teacher.

Analyze and Conclude

1. **Infer** Based on your model, what can you infer about the relative sizes of protons, neutrons, and electrons?
2. **Model** Why is it difficult to model the location of electrons?
3. **Key Concept** Compare your atom with those of other groups. How do they differ?

Substances

You can see that atoms make up most of the matter on Earth. Atoms can combine and arrange in millions of different ways. In fact, these different combinations and arrangements of atoms are what makes up the various types of matter. There are two main classifications of matter–substances and mixtures.

A **substance** *is matter with a composition that is always the same.* This means that a given substance is always made up of the same combination(s) of atoms. Aluminum, oxygen, water, and sugar are examples of substances. Any sample of aluminum is always made up of the same type of atoms, just as samples of oxygen, sugar, and water each are always made of the same combinations of atoms. To gain a better understanding of what makes up substances, let's take a look at the two types of substances–elements and compounds.

Key Concept Check What is a substance?

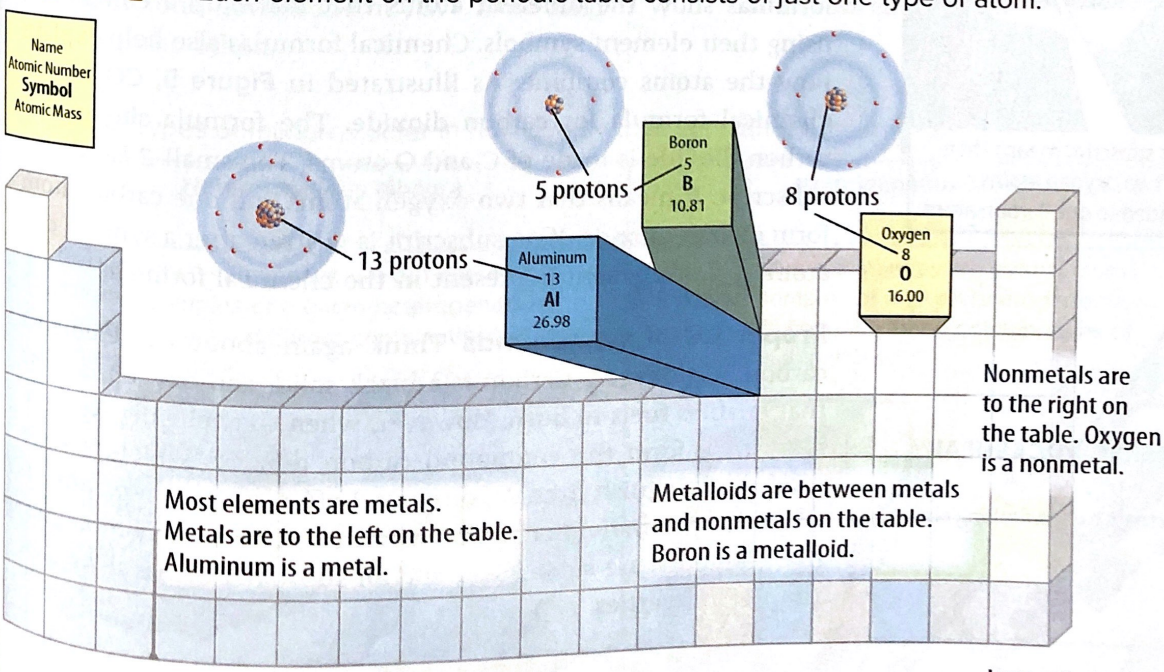
Elements

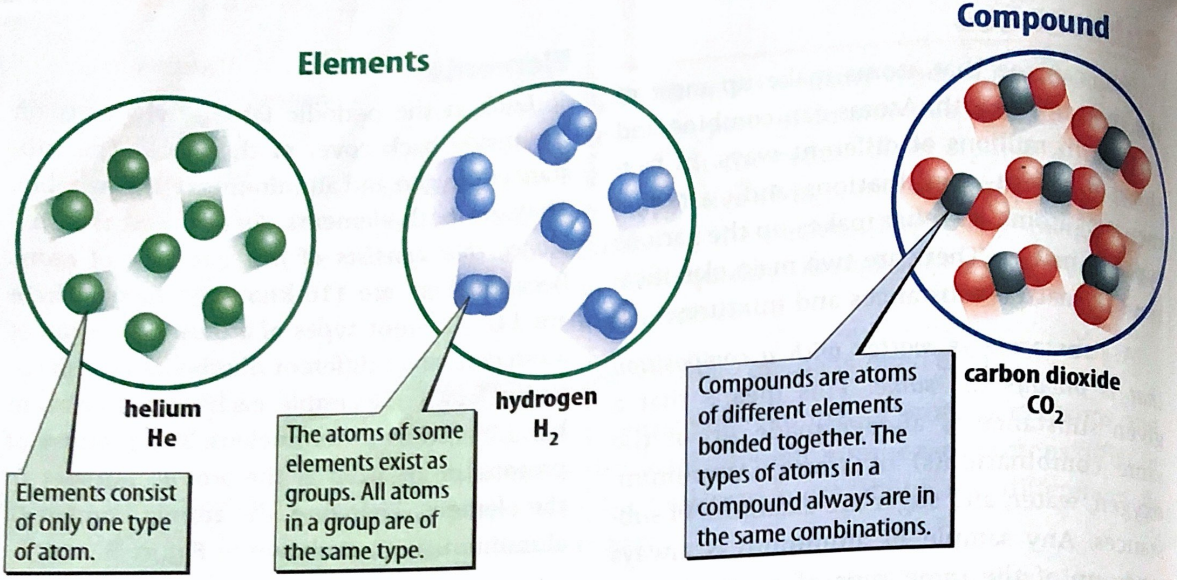
Look at the periodic table of elements on the inside back cover of this book. The substances oxygen and aluminum are on the table. They are both elements. *An* **element** *is a substance that consists of just one type of atom.* Because there are 118 known elements, there are 118 different types of atoms. Each type of atom contains a different number of protons in its nucleus. For example, each aluminum atom has 13 protons in its nucleus. The number of protons in an atom is the atomic number of the element. Therefore, the atomic number of aluminum is 13, as shown in **Figure 3.**

The atoms of most elements exist as individual atoms. For example, a roll of pure aluminum foil consists of trillions of individual aluminum atoms. However, the atoms of some elements usually exist in groups. For example, the oxygen atoms in air exist in pairs. Whether the atoms of an element exist individually or in groups, each element contains only one type of atom. Therefore, its composition is always the same.

Key Concept Check How do atoms of different elements differ?

Figure 3 Each element on the periodic table consists of just one type of atom.





▲ **Figure 4** If a substance contains only one type of atom, it is an element. If it contains more than one type of atom, it is a compound.

Compounds

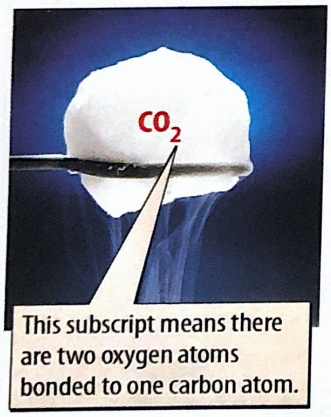
Water is a substance, but it is not an element. It is a compound. *A* **compound** *is a type of substance containing atoms of two or more different elements chemically bonded together.* As shown in **Figure 4**, carbon dioxide (CO_2) is also a compound. It consists of atoms of two different elements, carbon (C) and oxygen (O), bonded together. Carbon dioxide is a substance because the C and the O atoms are always combined in the same way.

Chemical Formulas The combination of symbols and numbers that represents a compound is called a chemical formula. Chemical formulas show the different atoms that make up a compound, using their element symbols. Chemical formulas also help explain how the atoms combine. As illustrated in **Figure 5**, CO_2 is the chemical formula for carbon dioxide. The formula shows that carbon dioxide is made of C and O atoms. The small *2* is called a subscript. It means that two oxygen atoms and one carbon atom form carbon dioxide. If no subscript is written after a symbol, one atom of that element is present in the chemical formula.

Properties of Compounds Think again about the elements carbon and oxygen. Carbon is a black solid, and oxygen is a gas that enables fuels to burn. However, when they chemically combine, they form the compound carbon dioxide, which is a gas used to extinguish fires. A compound often has different properties from the individual elements that compose it. Compounds, like elements, are substances, and all substances have their own **unique** properties.

Personal Tutor

Figure 5 Carbon dioxide is a compound composed of carbon and oxygen atoms. ▼



ACADEMIC VOCABULARY

unique
(adjective) having nothing else like it

Mixtures

Another classification of matter is mixtures. *A* **mixture** *is matter that can vary in composition.* Mixtures are combinations of two or more substances that are physically blended together. The amounts of the substances can vary in different parts of a mixture and from mixture to mixture. Think about sand mixed with water at the beach. The sand and the water do not bond together. Instead, they form a mixture. The substances in a mixture do not combine chemically. Therefore, they can be separated by physical methods, such as filtering.

Heterogeneous Mixtures

Mixtures can differ depending on how well the substances that make them up are mixed. Sand and water at the beach form a mixture, but the sand is not evenly mixed throughout the water. Therefore, sand and water form a heterogeneous mixture. *A* **heterogeneous mixture** *is a type of mixture in which the individual substances are not evenly mixed.* Because the substances in a heterogeneous mixture are not evenly mixed, two samples of the same mixture can have different amounts of the substances, as shown in **Figure 6.** For example, if you fill two buckets with sand and water at the beach, one bucket might have more sand in it than the other.

Homogeneous Mixtures

Unlike a mixture of water and sand, the substances in mixtures such as apple juice, air, or salt water are evenly mixed. *A* **homogeneous mixture** *is a type of mixture in which the individual substances are evenly mixed.* In a homogeneous mixture, the particles of individual substances are so small and well-mixed that they are not visible, even with most high-powered microscopes.

A homogeneous mixture also is known as a solution. In a solution, the substance present in the largest amount is called the solvent. All other substances in a solution are called solutes. The solutes dissolve in the solvent. *To* **dissolve** *means to form a solution by mixing evenly.* Because the substances in a solution, or homogeneous mixture, are evenly mixed, two samples from a solution will have the same amounts of each substance. For example, imagine pouring two glasses of apple juice from the same container. Each glass will contain the same substances (water, sugar, and other substances) in the same amounts. However, because apple juice is a mixture, the amounts of the substances from one container of apple juice to another might vary.

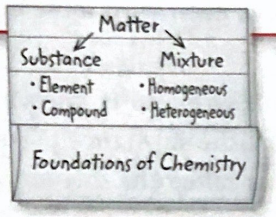
Key Concept Check How do mixtures differ from substances?

Figure 6 Types of mixtures differ in how evenly their substances are mixed.

Heterogeneous Mixture	Homogeneous Mixture
• The individual substances are not evenly mixed. • Different samples of a given heterogeneous mixture can have different combinations of the same substances.	• The individual substances are evenly mixed. • Different samples of a given homogeneous mixture will have the same combinations of the same substances.

FOLDABLES

Use three sheets of copy paper to make a layered Foldable. Cut and label the tabs as illustrated. Use this Foldable to summarize the lesson.



Compounds v. Solutions

If you have a glass of pure water and a glass of salt water, can you tell which is which just by looking at them? You cannot. Both the compound (water) and the solution (salt water) appear identical. How do compounds and solutions differ?

Because water is a compound, its composition does not vary. Pure water is always made up of the same atoms in the same combinations. Therefore, a chemical formula can be used to describe the atoms that make up water (H_2O). Salt water is a homogeneous mixture, or solution. The solute (NaCl) and the solvent (H_2O) are evenly mixed but are not bonded together. Adding more salt or more water only changes the relative amounts of the substances. In other words, the composition varies. Because composition can vary in a mixture, a chemical formula cannot be used to describe mixtures.

Summarizing Matter

You have read in this lesson about classifying matter by the arrangement of its atoms. **Figure 7** is a summary of this classification system.

Key Concept Check How can you classify matter?

Figure 7 Scientists classify matter according to the arrangement of the atoms that make up the matter.

Classifying Matter

Matter
- Anything that has mass and takes up space
- Matter on Earth is made up of atoms.
- Two classifications of matter: substances and mixtures

Substances
- Matter with a composition that is always the same
- Two types of substances: elements and compounds

Element
- Consists of just one type of atom
- Organized on the periodic table
- Each element has a chemical symbol.

Compound
- Two or more types of atoms bonded together
- Properties are different from the properties of the elements that make it up
- Each compound has a chemical formula.

Substances physically combine to form mixtures.

Mixtures can be separated into substances by physical methods.

Mixtures
- Matter that can vary in composition
- Substances are not bonded together.
- Two types of mixtures: heterogeneous and homogeneous

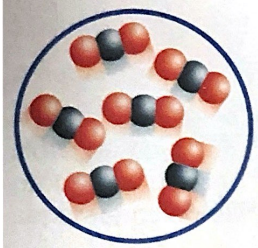
Heterogeneous Mixture
- Two or more substances unevenly mixed
- Different substances are visible by an unaided eye or a microscope.

Homogeneous Mixture—Solution
- Two or more substances evenly mixed
- Different substances cannot be seen even by a microscope.

Lesson 1 Review

Online Quiz

Visual Summary



A substance has the same composition throughout. A substance is either an element or a compound.

An atom is the smallest part of an element that has its properties. Atoms contain protons, neutrons, and electrons.

The substances in a mixture are not chemically combined. Mixtures can be either heterogeneous or homogeneous.

FOLDABLES®

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. The atoms in all objects are the same.
2. You cannot always tell by an object's appearance whether it is made of more than one type of atom.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

1. Substances and mixtures are two types of _____.
2. **Use the term** *atom* in a complete sentence.
3. **Define** *dissolve* in your own words.

Understand Key Concepts

4. **Explain** why aluminum is a substance.
5. The number of _____always differs in atoms of different elements.
   - A. electrons
   - B. protons
   - C. neutrons
   - D. nuclei
6. **Distinguish** between a heterogeneous mixture and a homogeneous mixture.
7. **Classify** Which term describes matter that is a substance made of different kinds of atoms bonded together?

Interpret Graphics

8. **Describe** what each letter and number means in the chemical formula below.

$$C_6H_{12}O_6$$

9. **Organize Information** Copy and fill in the graphic organizer below to classify matter by the arrangement of its atoms.

Type of Matter	Description

Critical Thinking

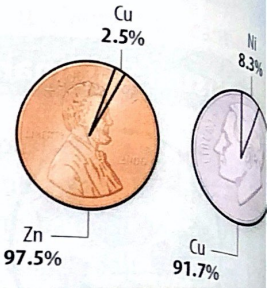
10. **Reorder** the elements aluminum, oxygen, fluorine, calcium, and hydrogen from the least to the greatest number of protons. Use the periodic table if needed.
11. **Evaluate** this statement: Substances are made of two or more types of elements.

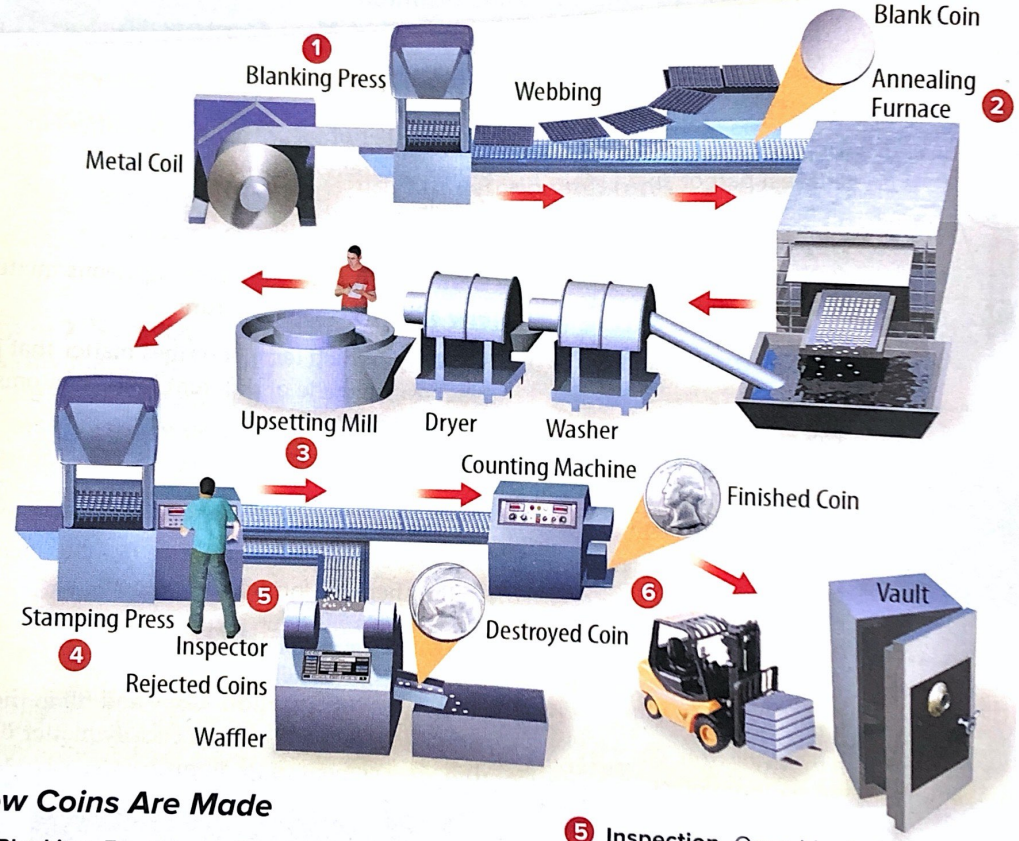
HOW IT WORKS

U.S. Mint

How Coins are Made

In 1793, the U.S. Mint produced more than 11,000 copper pennies and put them into circulation. Soon after, gold and silver coins were introduced as well. Early pennies were made of 95 percent copper and 5 percent zinc. Today's penny contains much more zinc than copper and is much less expensive to produce. Quarters, dimes, and nickels, once made of silver, are now made of copper-nickel alloy.





How Coins Are Made

1. **Blanking** For nickels, dimes, quarters, half-dollars, and coin dollars, a strip of 13-inch-wide metal is fed through a blanking press, which punches out round discs called blanks. The leftover webbing strip is saved for recycling. Ready-made blanks are purchased for making the penny.
2. **Annealing, Washing, Drying** Blanks are softened in an annealing furnace, which makes the metal less brittle. The blanks are then run through a washer and a dryer.
3. **Upsetting** Usable blanks are put through an upsetting mill, which creates a rim around the edges of each blank.
4. **Striking** The blanks then go to the stamping press, where they are imprinted with designs and inscriptions.
5. **Inspection** Once blanks leave the stamping press, inspectors check a few coins from each batch. Coins that are defective go to the waffler in preparation for recycling.
6. **Counting and Bagging** A machine counts the finished coins then drops them into large bags that are sealed shut. The coins are then taken to storage before being shipped to Federal Reserve Banks and then to your local bank.

It's Your Turn

COMPARE Collect a variety of coins that includes both older and current coins. Observe and compare their properties. Using the dates of the coins' production, utilize library or Internet sources to research the composition of metals used.