chapter 3 Atoms, Elements, and the Periodic Table

section 1 Structure of Matter

Before You Read

Take a deep breath. What fills your lungs? Can you see it or hold it in your hand?

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What You'll Learn

- what matter is
- what makes up matter
- the parts of an atom
- different atom models

Read to Learn

Study Coach

Make Flash Cards As you read, make flash cards to help you learn new science words. On one side of the card, write the word. On the other side of the card, write the definition. Review these cards as you study.

What is matter?

Is a glass with some water in it half empty or half full? Neither is correct. The glass is completely full. It is half full of water and half full of air. What is air? Air is a mixture of several gases, including nitrogen and oxygen. Nitrogen and oxygen are kinds of matter. **Matter** is anything that has mass and takes up space. So, even though you cannot see it or hold it, air is matter. Water also is matter. Most of the things you can see, taste, smell, and touch are made of matter.

What isn't matter?

You could not read the words on this page without light. Light has no mass and does not take up space. So, light is not matter. Is heat matter? Heat has no mass and does not take up space. So, heat is not matter. Your thoughts, feelings, and ideas are not matter, either. ☑

Reading Check

1. **List** three things that are not matter.

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What makes up matter?

Could you cut a piece of wood small enough so it no longer looks like wood? What is the smallest piece of wood you can cut? People have asked questions like these for hundreds of years. They wondered what matter is made of.

What was Democritus's idea of matter?

A Greek philosopher named Democritus lived from about 460 B.C. to 370 B.C. He thought the universe was made of empty space and tiny bits of stuff that he called atoms. The word *atom* comes from a Greek word that means "cannot be divided." Democritus believed atoms could not be divided into smaller pieces. Today, we define an **atom** as a particle that makes up most types of matter. The table below shows what Democritus thought about atoms. ☑

Reading Check

2. Summarize What is an atom?

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Democritus's Ideas About Atoms
1. All matter is made of atoms.
2. There are empty spaces between atoms.
3. Atoms are complete solids.
4. Atoms do not have anything inside them.
5. Atoms are different in size, shape, and weight.

Democritus also thought that different types of atoms existed for every type of matter. He thought the different atoms explained the different characteristics of each type of matter. Democritus's ideas about atoms were a first step toward understanding matter. In the early 1800s, scientists started building on the concept of atoms to form the current atomic theory of matter.

Can matter be made or destroyed?

For many years, people thought matter disappeared when it burned or rusted. Seeing objects grow, like trees, also made them think that matter could be made. A French chemist named Lavoisier (la VWAH see ay) lived about 2,000 years after Democritus. Lavoisier studied wood fires very carefully. Lavoisier showed that wood and the oxygen it combines with during a fire have the same mass as the ash, gases, and water vapor that are produced by the fire. So, matter is not destroyed when wood burns. It just changes into a different form.

Applying Math

3. Apply Suppose you increase the mass of wood you are burning in a fireplace. What will happen to the total mass of ash, gases, and water vapor?

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$$\text{total mass of wood} + \text{oxygen} = \text{total mass of ash} + \text{gases} + \text{water vapor}$$

From Lavoisier's work came the law of conservation of matter. The **law of conservation of matter** states that matter is not created or destroyed—matter only changes form.

Models of the Atom

Models often are used for things that are too small or too large to be observed. Models also are used for things that are difficult to understand.

Smaller Models One way to make a model is to make a smaller version of something that is large. If you want to design a new sailboat, would you build a full-sized sailboat and hope it would float? It would be safer and cheaper to build and test a smaller version first. Then, if it didn't float, you could change your design and just build another model, not another full-sized sailboat. You could keep trying until the model worked.

Larger Models Scientists sometimes make models that are larger than the actual objects. Atoms are too small to see. So, scientists use large models of atoms to explain data or facts that are found during experiments. This means these models are also theories.

What was Dalton's model of an atom?

John Dalton was an English chemist. In the early 1800s, he made an atomic model that explained the results of the experiments of Lavoisier and others.

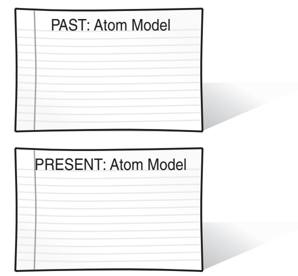
Dalton's atomic model was a set of ideas instead of an object. He believed matter was made of atoms that were too small to see. He also thought that each type of matter was made of only one kind of atom. For example, gold rings were made of gold atoms. Iron atoms made up an iron bar. Dalton also thought gold atoms are different from iron atoms. The different types of atoms explain why gold and iron are different. Other scientists made experiments and gathered data based on Dalton's model. Dalton's model became known as the atomic theory of matter. ☑

How small is an atom?

Atoms are so small it would take about 1 million of them lined up in a row to be about as thick as one human hair. Or, imagine you are holding an orange. If you want to see the atoms on the orange's skin, the orange would need to be as big as Earth. Then, imagine the Earth-sized orange covered with billions of marbles. Each marble would represent an atom on the skin of the orange.

FOLDABLES™

A Compare and Contrast Use two half-sheets of notebook paper to compare the past atomic model and the present atomic model.



Reading Check

4. Explain Dalton's atomic model was not an object. What was it?

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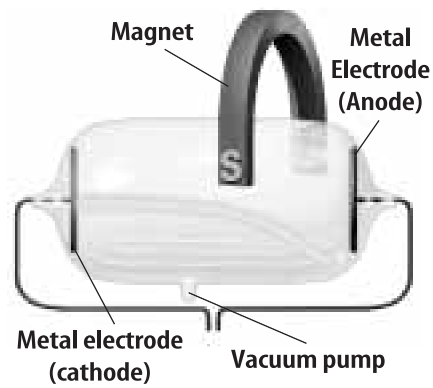
What is an electron?

An English scientist named J.J. Thomson discovered the electron in the early 1900s. He experimented using a glass tube with a metal plate at each end, like the one in the figure below. Thomson connected the metal plates to electricity. One plate, called the anode, had a positive charge. The other plate, called the cathode, had a negative charge.



Picture This

5. Highlight Highlight the area in the figure to show where the positive charge was in Thomson's experiment.

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During his experiments, Thomson watched rays travel from the cathode to the anode. Then, he used a magnet to bend the rays. Since the rays could be bent, they were made of particles that had mass and charge. He knew that like charges repel each other and opposite charges attract each other. Since the rays were traveling to the positive plate (the anode), Thomson decided the rays must be made of particles with negative charges. These invisible particles with negative charges are **electrons.** Thomson showed that atoms can be divided into smaller particles.

Think it Over

6. Explain Why was Thomson's discovery important?

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What was Thomson's model of the atom?

Matter that has an equal amount of positive and negative charge is neutral. Most matter is neutral. So, Thomson thought an atom was made of a ball of positive charge with negatively charged electrons in it. ☑

Thomson's model of an atom was like a ball of chocolate chip cookie dough. The dough was positively charged. The chocolate chips were the negatively charged electrons.

Reading Check

7. Locate Information What did Thompson think an atom was made of?

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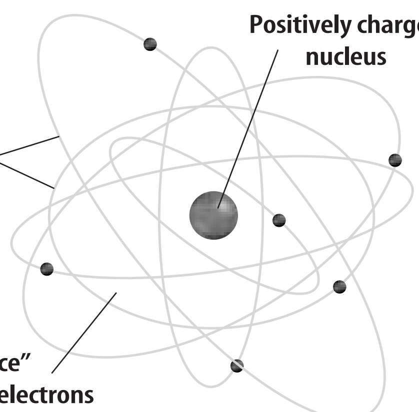
What was Rutherford's model of the atom?

Scientists still had questions about how the atom was arranged and about particles with positive charge. Around the year 1910, an English scientist named Ernest Rutherford and his team of scientists tried to answer these questions.

Rutherford's experiment Rutherford's team shot tiny, high-energy, positively charged particles, or alpha particles, at a very thin piece of gold foil. Rutherford thought that the alpha particles would pass easily through the foil. Most of the alpha particles did pass straight through. But, other alpha particles changed direction. A few of them even bounced back.

Since most particles passed straight through the gold, Rutherford thought that the gold atoms must be made of mostly empty space. But, because a few particles bounced off something, the gold atoms must have some positively charged object within the empty space. He called this positively charged object the nucleus. The **nucleus** (NEW klee us) is the positively charged, central part of an atom. Rutherford named the positively charged particles in the nucleus of an atom **protons.** He also suggested that negatively charged electrons were scattered in the empty space around the nucleus. Rutherford's model is shown in the figure below.



Picture This

8. **Draw Conclusions** In Rutherford's model, what is an atom *mostly* made of?

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How was the neutron discovered?

Rutherford was puzzled by one observation in his experiment with alpha particles. The nucleus of an atom seemed to be heavier after the experiment. He did not know where this extra mass came from. James Chadwick, one of Rutherford's students, answered the question: The nuclei were not getting heavier. But, the atoms had given off new particles. He found that the path of the new particles was not affected by an electric field. This meant the new particles were neutral—had no charge. Chadwick called these new particles neutrons. A **neutron** (NEW trahn) is a neutral particle in the nucleus of an atom. His proton-neutron model of the nucleus of an atom is still accepted today. ✔

✔ Reading Check

9. **Identify** What type of charge do neutrons have?

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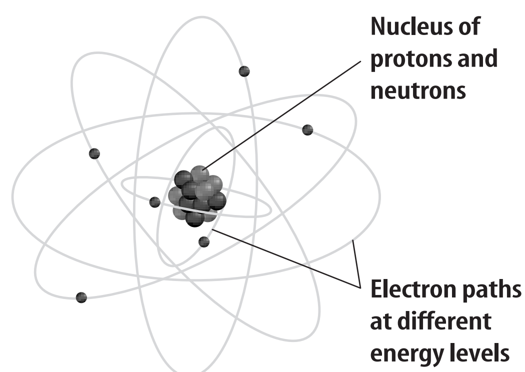
Improving the Atomic Model

A scientist named Niels Bohr found that electrons are arranged in energy levels in an atom. The figure shows his model. The lowest energy level is closest to the nucleus. It can have only two electrons. Higher energy levels are farther from the nucleus. They can have more than two electrons. To explain these energy levels, some scientists thought that electrons might orbit, or travel, around the atom's nucleus. The electrons were thought to travel in paths that are specific distances from the nucleus. This is similar to how the planets travel around the Sun.

Bohr's Model of an Atom



Picture This

10. Compare and Contrast How is Bohr's atomic model different from the modern atomic model?

Bohr's model:

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Modern model:

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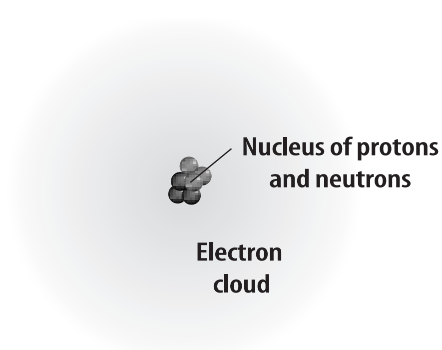
What is the modern atomic model?

Today, scientists realize that electrons have characteristics similar to both waves and particles. So, electrons do not orbit the nucleus of an atom in paths. Instead, electrons move in a cloud around the nucleus, as shown in the figure. The dark area shows where the electron is most likely to be in the electron cloud.

Modern Model of an Atom



After You Read

Mini Glossary

atom: a small particle that makes up most types of matter

electron: an invisible particle with a negative charge around the nucleus of an atom

law of conservation of matter: matter is not created or destroyed—matter only changes form

matter: anything that has mass and takes up space

neutron: (NEW trahn) a neutral particle in the nucleus of an atom

nucleus: (NEW klee us) the positively charged, central part of an atom

proton: positively charged particle in the nucleus of an atom

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain the law of conservation of matter.

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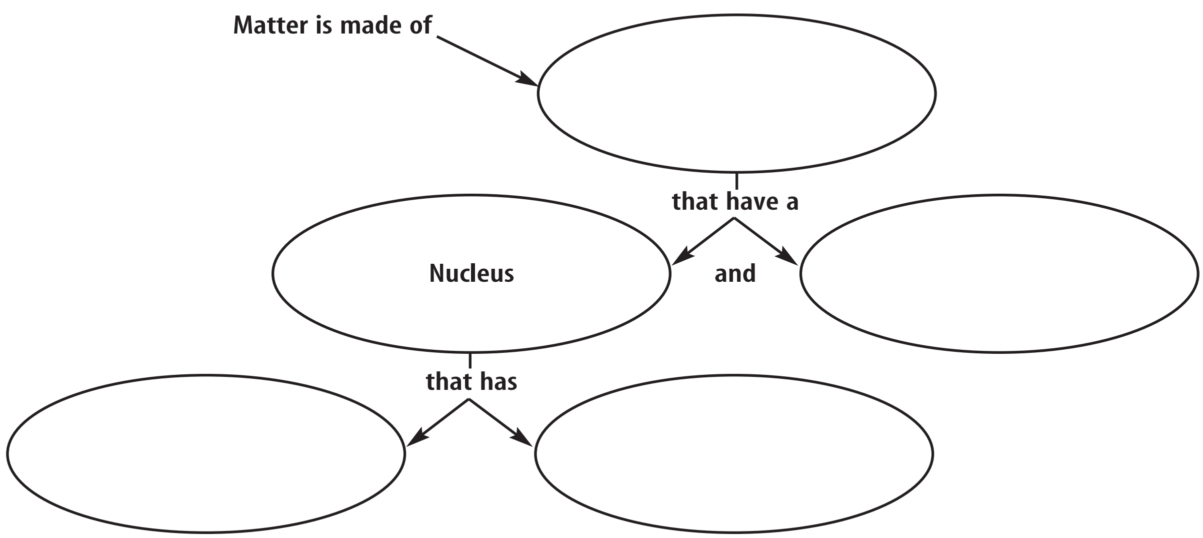
2. Fill in each blank in the concept map.



3. How could you explain the modern atomic model to another student?

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End of Section

chapter 3

Atoms, Elements, and the Periodic Table

section 2 The Simplest Matter

What You'll Learn

- about elements in the periodic table
- what atomic mass and atomic number are
- what an isotope is
- about metals, metalloids, and nonmetals

Before You Read

Have you ever taken something apart to see what it was made of? Describe a time when you did this.

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Mark the Text

Highlighting As you read, highlight the main ideas under each heading. After you finish reading, review the main ideas of the lesson.

Read to Learn

The Elements

An **element** is matter made of only one kind of atom. For example, gold is made of only gold atoms. At least 110 elements are known. About 90 elements are found naturally on Earth, for example, oxygen, nitrogen, and gold. Some elements are not found in nature. These are called synthetic elements. Synthetic elements are used in smoke detectors and heart pacemaker batteries.

Applying Math

1. **Calculate** About how many elements are synthetic elements?

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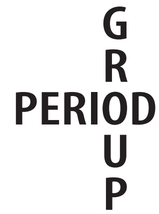
The Periodic Table

How would you find a certain book in a library? If you look at the books on the shelves as you walk past, you probably won't find the book you want. Libraries organize the books to help you quickly find the ones you want.

Scientists organize information about the elements, too. They created a chart called the periodic table of the elements. Each element in the chart has a chemical symbol. The symbols have one to three letters. The symbol for oxygen is O. The symbol for aluminum is Al. Scientists all over the world use these chemical symbols.

How are elements listed in the periodic table?

The periodic table has rows and columns that show how the elements relate to one another. The elements are grouped by their properties. The rows go from left to right and are called periods. The elements in a period have the same number of energy levels. The columns go up and down and are called groups. The elements in a group have similar properties related to their structures. They also tend to form similar bonds. The figure may help you remember the difference between periods and groups in the periodic table.

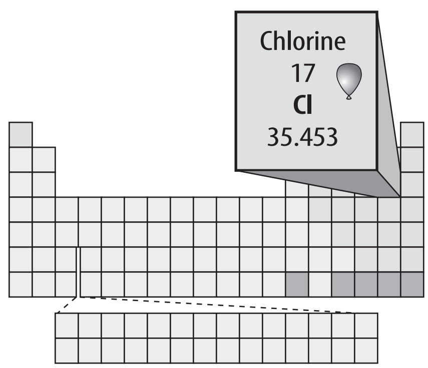


Identifying Characteristics

Each element is different and has unique properties. These differences can be described by looking at the relationships between the atomic particles, or parts of the atoms, in each element. Numbers in the periodic table describe these relationships.

What is the atomic number of an element?

The figure shows the periodic table block for chlorine. The symbol for chlorine is Cl. The number at the top, 17, is the atomic number for chlorine. The **atomic number** is the number of protons in the nucleus of each atom of an element. So, every chlorine atom has 17 protons in its nucleus. Each element in the periodic table has a different atomic number. This means that each element has a different number of protons in its nucleus. ☑



What is an isotope?

The atomic number, or number of protons in the nucleus, is always the same for an element. But the number of neutrons in the nucleus is not always the same. For example, some chlorine atoms have 18 neutrons and some have 20 neutrons. Chlorine-35 is a chlorine atom that has 18 neutrons. Chlorine-37 has 20 neutrons. These two chlorine atoms are isotopes. **Isotopes** (I suh tohps) are atoms of the same element that have different numbers of neutrons.

Picture This

2. **Locate** To help you remember the location of periods and groups in a periodic table, draw an arrow pointing left and right through PERIOD. Then draw an arrow pointing up and down through GROUP.

Picture This

3. **Locate** Circle the atomic number for chlorine in the periodic table block.

Reading Check

4. **Define** What does the atomic number of an atom represent?

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Picture This

5. Read a Table How many neutrons does chlorine-37 have?

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What is a mass number?

You can refer to a certain isotope by using its mass number. An atom's **mass number** is the number of protons plus the number of neutrons in its nucleus. Look at the table below. Chlorine-35 has a mass number of 35 because the number of protons (17) plus the number of neutrons (18) equals 35. The isotope is named chlorine-35 because its mass number is 35.

Isotope	Number of protons		Number of neutrons	Mass number
Chlorine-35:	17	+	18	35
Chlorine-37:	17	+	20	37

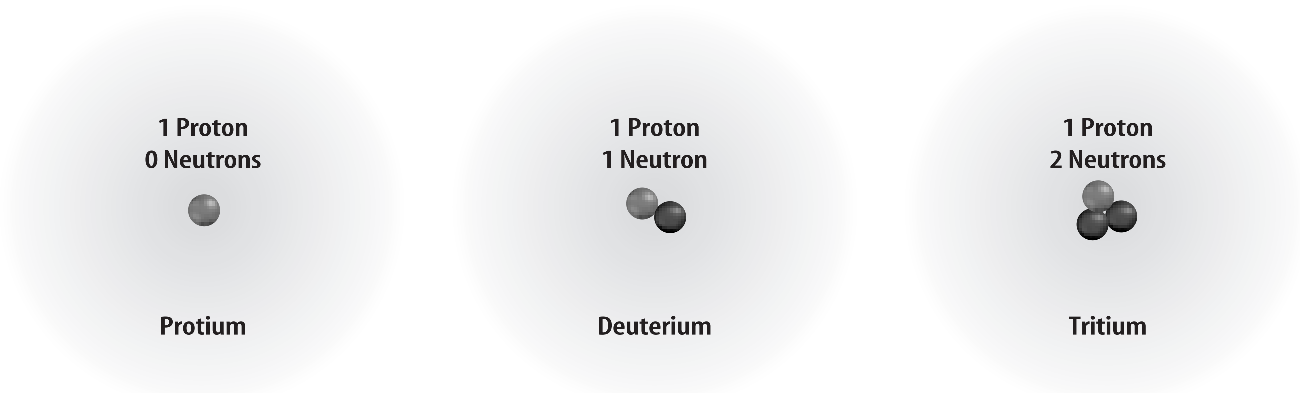
Picture This

6. Understanding Figures What is the mass number of the hydrogen isotope deuterium?

Every particle in the nucleus adds to the mass of an atom. So, if an atom has more neutrons, its mass is greater. If it has fewer neutrons, its mass is less. The mass of chlorine-37 is greater than the mass of chlorine-35.

Hydrogen is the first element in the periodic table. Hydrogen has three isotopes with mass numbers of 1, 2, and 3, shown below. Every hydrogen atom always has one proton. Each isotope has a different number of neutrons.

Isotopes of Hydrogen



What is atomic mass?

The number below an element's chemical symbol is the atomic mass. **Atomic mass** is the average mass of all the isotopes of an element. The atomic mass takes into account how often the isotopes are found. For chlorine, the atomic mass is 35.45 u. The letter *u* stands for "atomic mass unit," the unit of measure for atomic mass.

Classification of Elements

The elements are divided into three classes or categories—metals, metalloids (ME tuh loydz), and nonmetals. The elements in each category have similar properties.

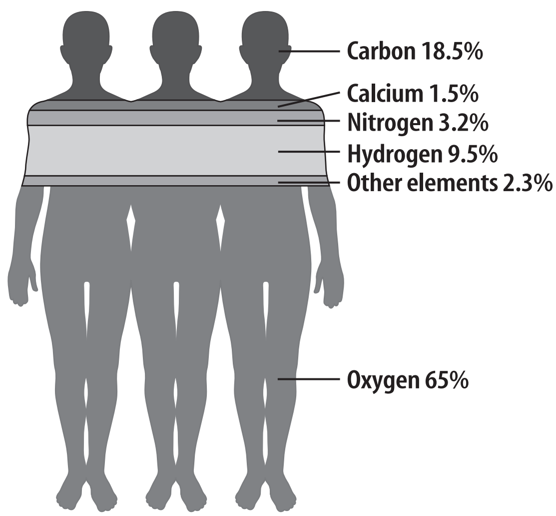
What are some properties of metals?

Metals are elements that have a shiny or metallic appearance and are good conductors of heat and electricity. All metals, except mercury, are solids at room temperature. Metals also are malleable (MAL yuh bul). Malleable means they can be bent and pounded into shapes. Metals are ductile. Ductile means they can be stretched into wires without breaking. Gold, silver, iron, copper, and lead are examples of metals. Most of the elements in the periodic table are metals.

What are some properties of nonmetals?

Nonmetals are elements that usually look dull and are poor conductors of heat and electricity. They are brittle, which means they cannot change shape easily without breaking. You cannot stretch or bend brittle materials. Many nonmetals are gases at room temperature.

Nonmetals are important to life. Look at the figure. More than 97 percent of your body is made up of different nonmetals. Examples of nonmetals include chlorine, oxygen, hydrogen, nitrogen, and carbon. Most of the elements on the right side of the periodic table are nonmetals.

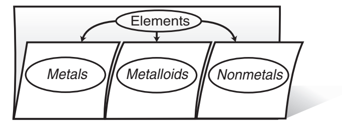


What are some properties of metalloids?

Metalloids are elements that have properties of both metals and nonmetals. All metalloids are solids at room temperature. Some metalloids are shiny. Many metalloids can conduct heat and electricity, but not as well as metals can. On the periodic table, metalloids are found between metals and nonmetals. Silicon is an example of a metalloid. It is used in electronic circuits in computers and televisions.

FOLDABLES™

B Compare and Contrast Make the Foldable below to help you understand how metals, metalloids, and nonmetals are alike and different.



Reading Check

7. **Conclude** Most of the elements in the periodic table are metals. Is this sentence true or false? Circle your answer.
   True **False**

Picture This

8. **Compare** Which nonmetal is found the most in your body?

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After You Read

Mini Glossary

atomic mass: the average mass of all the isotopes of an element

atomic number: the number of protons in the nucleus of each atom of an element

element: matter made of only one kind of atom

isotope: (I suh tohps) atoms of the same element that have a different number of neutrons

mass number: the number of protons plus the number of neutrons in the nucleus of each atom of an element

metalloids: elements that have properties of both metals and nonmetals

metals: elements that have a shiny, or metallic, appearance and are good conductors of heat and electricity

nonmetals: elements that usually looks dull and are poor conductors of heat and electricity

1. Review the terms and their definitions in the Mini Glossary. Which two terms describe numbers that appear in an element's square on the periodic table?

2. Complete the table to identify properties of metals, metalloids, and nonmetals.

Properties	Metals	Metalloids	Nonmetals
Appearance—how they look			
Ability to conduct heat and electricity			
Ability to bend and stretch			

3. You were asked to highlight the main ideas under each heading. How did you decide what the main ideas were?

End of Section

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chapter 3

Atoms, Elements, and the Periodic Table

section 3 Compounds and Mixtures

Before You Read

If you mix together salt and water, what happens to the salt? What happens to the water?

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What You'll Learn
- what a compound is
- how different types of mixtures are similar and different

Read to Learn

Substances

Scientists classify matter depending on what it is made of and how it behaves. Matter that has the same composition and properties throughout is a **substance.** Elements such as gold and aluminum are substances. Substances also can be two or more elements combined, like brass. Brass is made of copper and zinc.

What is a compound?

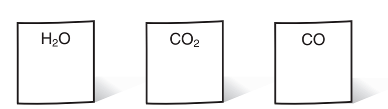
A **compound** is a substance whose smallest unit is made up of atoms of more than one element bonded together. Water is a compound. It is made up of hydrogen and oxygen. Hydrogen and oxygen are both colorless gases. But, when they are combined, they make water. Water is sometimes written as H_2O. H stands for hydrogen and O stands for oxygen. Many compounds have properties that are different from those of its elements. For example, water is different from the gases hydrogen and oxygen. It also is different from hydrogen peroxide (H_2O_2), another compound made from hydrogen and oxygen.

Study Coach

Create a Quiz As you read this section, write a quiz question for each paragraph. After you finish reading the section, answer your quiz questions.

FOLDABLES™

C Identify Make the following Foldables from quarter-sheets of notebook paper to help you identify the differences between H_2O, C_2O, and CO.



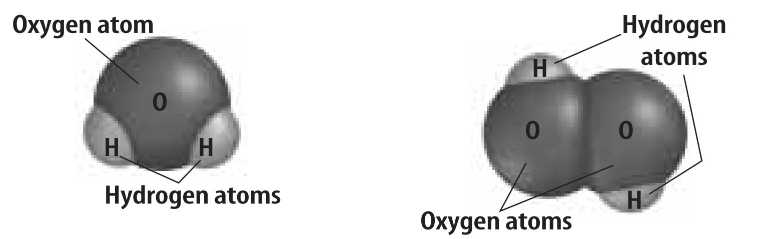
What is a chemical formula?

Compounds have chemical formulas. A chemical formula shows the elements that make up a compound. It also shows how many atoms of each element are in the compound. For example, H_2O is the chemical formula of water. The small number to the right of an element tells how many atoms are in one unit, or molecule, of that compound. When no number is written, the molecule has one atom of that element. So, a molecule of water is made up of two atoms of hydrogen and one atom of oxygen.

H_2O_2 is the chemical formula for hydrogen peroxide. It has two hydrogen atoms and two oxygen atoms. So, the elements hydrogen and oxygen form two compounds—water and hydrogen peroxide. Look at the figures below to see the differences in their structure. The properties of water are very different from the properties of hydrogen peroxide.

Picture This

1. **Circle** the chemical formula in each figure.



H_2O Water H_2O_2 Hydrogen Peroxide

Think it Over

2. **Identify** What is the chemical formula for carbon dioxide?

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Are compounds always the same?

A given compound always is made of the same elements and in the same proportion, or ratio. For example, one unit of water is always made of two hydrogen atoms and one oxygen atom. You can write the number of molecules of water that you have by putting a number in front of the formula. So, 6 H_2O means you have six molecules of water.

Mixtures

A mixture is made when two or more substances come together but do not combine to make a new substance. The substances can be elements, compounds, or elements and compounds. The proportions of the substances in a mixture can be changed without changing the identity of the mixture, unlike in a compound. Sand and water form a mixture. If you add more sand to the mixture, you still have a mixture of sand and water.

Air Another example of a mixture is air. Air is made of nitrogen, oxygen, and many other gases. There can be different amounts of these gases in the mixture. But you still have a mixture of air.

You see mixtures every day. A salad of lettuce, tomatoes, and cucumbers is a mixture. The mixture may have more tomatoes than cucumbers, but it is still a salad.

How can mixtures be separated?

You can separate many mixtures. A mixture of solids can be separated by using different screens or filters. For example, you could separate a mixture of pebbles and sand by pouring the mixture through a screen. The screen can catch the pebbles, but let the sand go through.

You also can use a liquid to separate some mixtures of solids. If you add water to a mixture of sugar and sand, only the sugar will dissolve in the water. Then, you can pour the mixture through a filter that catches the sand. Next, you can separate the sugar from the water by heating it. As shown in the figure, even your blood is a mixture that can be separated.

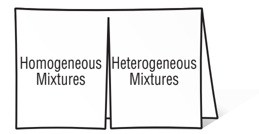
What are homogeneous and heterogeneous mixtures?

Homogeneous Mixtures Homogeneous means "the same throughout." So, homogeneous mixtures are those that look the same throughout. You cannot see the different parts of the mixture. Since you can't see the different parts, you might not know it is a mixture. Homogeneous mixtures can be solids, liquids, or gases. Brass, sugar water, and air are mixtures.

Heterogeneous Mixtures Heterogeneous means "completely different." Heterogeneous mixtures have larger parts that are different from each other. You can see the different parts of a heterogeneous mixture. Vegetable soup is a heterogeneous mixture.

FOLDABLES™

D Contrast Make the following 2-tab Foldable to help you learn the differences between homogeneous mixtures and heterogeneous mixtures.



Reading Check

3. Explain How is a heterogeneous mixture different from a homogeneous mixture?

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After You Read

Mini Glossary

compound: a substance whose smallest unit is made up of atoms of more than one element bonded together

mixture: made when two or more substances come together but do not combine to make a new substance

substance: matter that has the same composition and properties throughout

1. Review the terms and definitions in the Mini Glossary. In your own words, describe the difference between a compound and a mixture.

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2. Complete the chart below to compare the substances discussed in this section.

Substance	Definition	Examples
Element		
Compound		
Mixture		

End of Section