Section 1

Elements and Atoms

Reading Preview

Key Concepts

- Why are elements sometimes called the building blocks of matter?
- How did atomic theory develop and change?

Key Terms

- matter • element
- compound • mixture • atom
- scientific theory • model
- electrons • nucleus • protons
- energy level • neutrons

Target Reading Skill

Outlining An outline shows the relationship between main ideas and supporting details. As you read, make an outline about elements and atoms. Use the red headings for the main ideas and the blue headings for the supporting ideas.

Elements and Atoms

I. The building blocks of matter
   A. Elements, compounds, and mixtures
   B.
II. Atomic theory and models
   A.
   B.

Lab zone Discover Activity

How Far Away Is the Electron?

1. On a piece of paper, make a small circle no bigger than a dime. The circle represents the nucleus, or center, of an atom.
2. Measure the diameter of the circle in centimeters.
3. Now predict where the outer edge of this model atom would be. For example, would the outer edge be within the edges of the paper? Your desk? The classroom? The school building?

Think It Over

Calculating The diameter of an actual atom can be 100,000 times the diameter of its nucleus. Calculate the diameter of your model atom. How close was your prediction in Step 3 to your calculation? (*Hint:* To understand the scale of your answer, change the units of measurement from centimeters to meters.)

If you take a quick look around you, you will see many examples of matter. Buildings made of wood or steel, forks and spoons made of metal, your clothing, water, the air you breathe, and all living things are matter. **Matter** is anything that has mass and takes up space. But what is matter made of? More than 2,000 years ago, the ancient Greeks believed that all matter was made up of four elements—air, earth, fire, and water. Not until much later did scientists begin to realize that matter was composed of many different elements.

The Building Blocks of Matter

Elements are the simplest pure substances, and they cannot be broken down into any other substances. You are already familiar with many elements. Aluminum, iron, copper, lead, oxygen, chlorine, neon, and helium are a few you might know. But how are elements related to the many other materials you find in your world? **Elements are often called the building blocks of matter because all matter is composed of one element or a combination of two or more elements.**

Elements, Compounds, and Mixtures Elements usually exist in combination with other elements in the form of compounds. A **compound** is a pure substance made of two or more elements that are combined chemically in a specific ratio. For example, sodium chloride (table salt) from underground mines or from seawater is always 39.3 percent sodium and 60.7 percent chlorine by mass.

Elements can also mix with other elements *without* combining chemically. The air you breathe, for example, consists mostly of nitrogen gas and oxygen gas that are separate substances. A **mixture** is two or more substances—elements, compounds, or both—that are in the same place but are not chemically combined. Air, soil, wood, gasoline, concrete, and orange juice are a few of the many mixtures in your world.

Particles of Elements If elements are the simplest forms of matter, do you wonder what the smallest piece of an element is? If you cut a copper wire in half over and over again, could you keep cutting it forever? Or would you reach a point where you have the smallest possible piece of copper?

Again, the first people to think about this question were the ancient Greeks. Around the year 430 B.C., a Greek philosopher named Democritus proposed the idea that matter is formed of small pieces that could not be cut into smaller parts. He used the word *atomos*, which means "uncuttable," for these smallest possible pieces. In modern terms, an **atom** is the smallest particle of an element. The Greek idea of atoms had to wait about 2,000 years before it became accepted.

Reading Checkpoint **How is a compound different from an element?**

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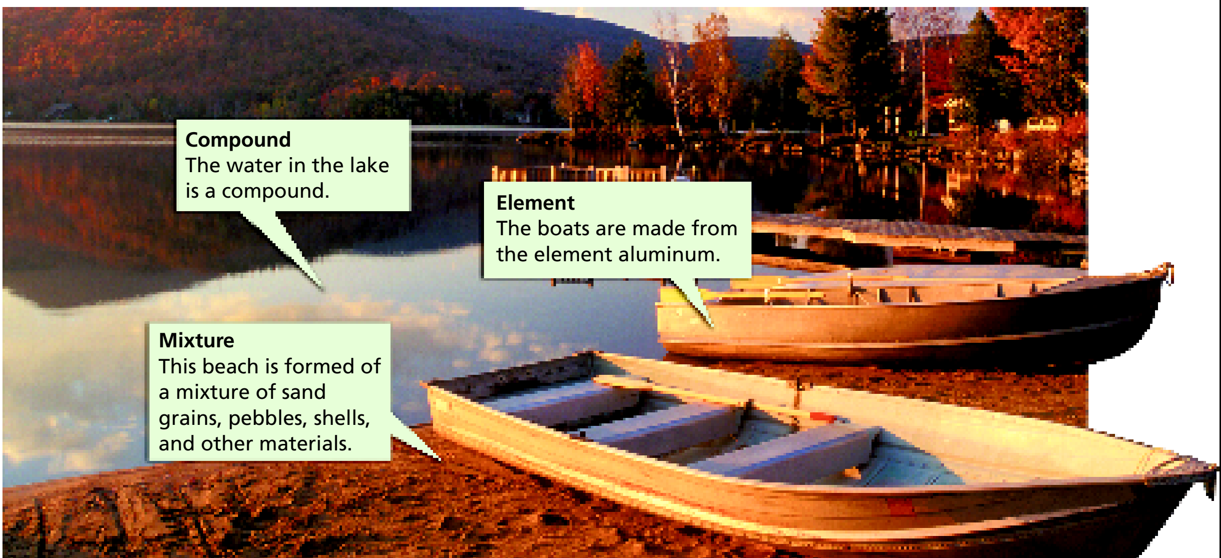
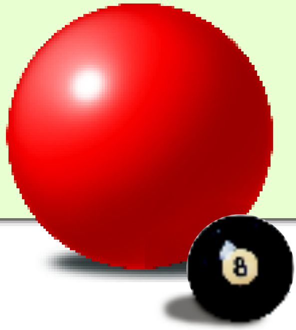


FIGURE 1
Kinds of Matter
Matter may consist of elements, compounds, or mixtures.
Inferring *What other mixture besides sand is present, but not visible, in the photo?*

FIGURE 2
Dalton Model
Dalton thought that atoms were like smooth, hard balls that could not be broken into smaller pieces.



Summary of Dalton's Ideas

- All elements are composed of atoms that cannot be divided.
- All atoms of the same element are exactly alike and have the same mass. Atoms of different elements are different and have different masses.
- An atom of one element cannot be changed into an atom of a different element. Atoms cannot be created or destroyed in any chemical change, only rearranged.
- Every compound is composed of atoms of different elements, combined in a specific ratio.

Atomic Theory and Models

The ancient Greeks did not prove the existence of atoms because they did not do experiments. In science, ideas are just ideas unless they can be tested. The idea of atoms began to develop again in the 1600s. This time, people did do experiments. As a result, atomic theory began to take shape.

A **scientific theory** is a well-tested idea that explains and connects a wide range of observations. Theories often include **models**—physical, mental, visual, and other representations of an idea to help people understand what they cannot observe directly. **Atomic theory grew as a series of models that developed from experimental evidence. As more evidence was collected, the theory and models were revised.**

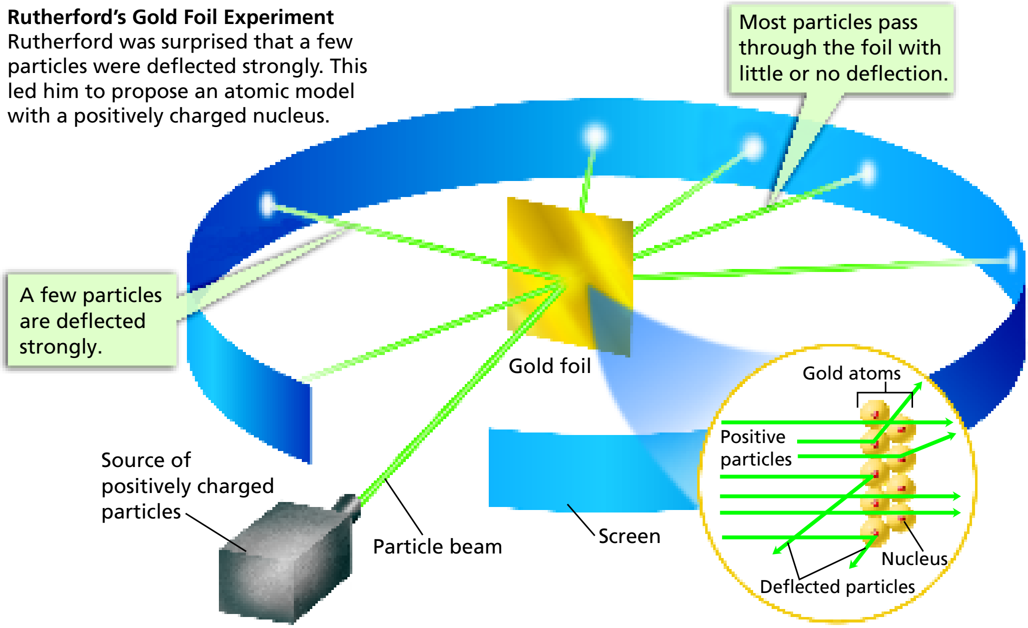
Dalton's Atomic Theory Using evidence from many experiments, John Dalton, an English chemist, began to propose his atomic theory and model for atoms. The main ideas of Dalton's theory are summarized in Figure 2. With only a few changes, Dalton's atomic theory is still accepted today.

Thomson and Smaller Parts of Atoms Through a series of experiments around the start of the twentieth century, scientists discovered that atoms are made of even smaller parts. In 1897, another British scientist, J. J. Thomson, found that atoms contain negatively charged particles. Yet, scientists knew that atoms themselves had no electrical charge. So, Thomson reasoned, atoms must also contain some sort of positive charge.

Thomson proposed a model like the one in Figure 3. He described an atom that consisted of negative charges scattered throughout a ball of positive charge—something like raisins or berries in a muffin. The negatively charged particles later became known as **electrons.**

FIGURE 3
Thomson Model
Thomson suggested that atoms had negatively charged electrons embedded in a positive sphere.
Comparing and Contrasting *How is Thomson's model different from Dalton's?*

FIGURE 4
Rutherford's Gold Foil Experiment
Rutherford was surprised that a few particles were deflected strongly. This led him to propose an atomic model with a positively charged nucleus.

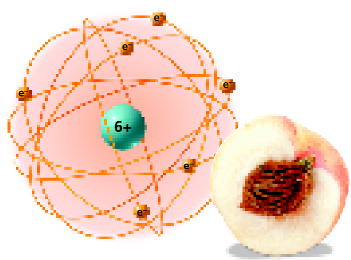


Rutherford and the Nucleus In 1911, one of Thomson's students, Ernest Rutherford, found evidence that countered Thomson's model. In an experiment diagrammed in Figure 4, Rutherford's research team aimed a beam of positively charged particles at a thin sheet of gold foil. They predicted that, if Thomson's model were correct, the charged particles would pass right through the foil in a straight line. The gold atoms would not have enough positive charge in any one region to strongly repel the charged particles.

Rutherford's team observed that most of the particles passed through the foil undisturbed, as expected. But, to their surprise, a few particles were deflected strongly. Since like charges repel each other, Rutherford inferred that an atom's positive charge must be clustered in a tiny region in its center, called the **nucleus** (NOO klee us). Those particles that were deflected strongly had been repelled by a gold atom's nucleus.

Scientists knew from other experiments that electrons had almost no mass. Therefore, they reasoned that nearly all of an atom's mass must also be located in the tiny, positively charged nucleus. In Rutherford's model of the atom, the atom was mostly empty space with electrons moving around the nucleus in that space. Later, Rutherford named the positively charged particles in the nucleus of an atom **protons.**

FIGURE 5
Rutherford Model
According to Rutherford's model, an atom was mostly empty space. Electrons moved around a small, positively charged nucleus in the center of the atom.

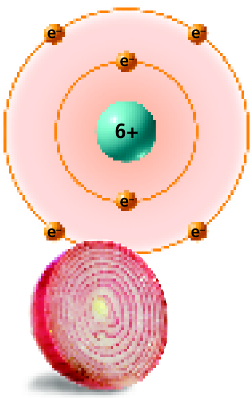


Bohr's Model In 1913, Niels Bohr, a Danish scientist and a student of both Thomson and Rutherford, revised the atomic model again. Bohr showed that electrons could have only specific amounts of energy, leading them to move in certain orbits. The series of orbits in Bohr's model resemble planets orbiting the sun or the layers of an onion.

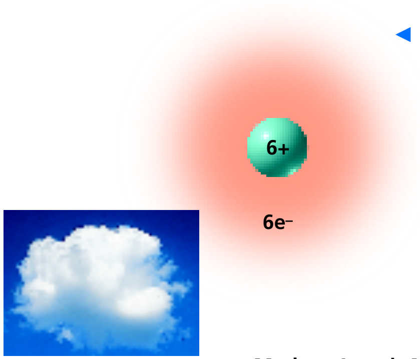
A Cloud of Electrons In the 1920s, the atomic model changed again. Scientists determined that electrons do not orbit the nucleus like planets. Instead, electrons can be anywhere in a cloudlike region around the nucleus. A region around the nucleus in which electrons of the same energy are likely to be found is called an **energy level.** The lowest-energy electrons are in an energy level near the nucleus that can hold only 2 electrons. Higher-energy electrons are in larger energy levels farther from the nucleus. These larger energy levels can hold 8 or more electrons.

The Modern Atomic Model In 1932, British scientist James Chadwick discovered another particle in the nucleus of atoms. His discovery completed the modern atomic model. This new particle was hard to detect because it has no electrical charge even though it has nearly the same mass as a proton. Because the particle was electrically neutral, it was called a **neutron.**

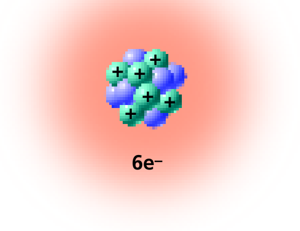
FIGURE 6
Later Atomic Models
Through the first part of the twentieth century, atomic models continued to change.
Interpreting Diagrams *How does the cloud model differ from the modern atomic model?*



Bohr Model
Niels Bohr suggested that electrons move in specific orbits around the nucleus of an atom.



Cloud Model
According to the cloud model, electrons move rapidly in every direction around the nucleus.



Modern Atomic Model
The nucleus, which contains both protons and neutrons, is surrounded by a cloudlike region of electrons.

New research continues to provide data that support this model of a small nucleus surrounded by a cloudlike region of electrons. The nucleus contains protons and neutrons that together make up nearly all of an atom's mass. The only exception is the nucleus of the hydrogen atom, which usually consists of a single proton. A cloud of electrons made of a series of energy levels occupies most of the volume of an atom.

If you did the Discover activity at the beginning of this section, you learned that the size of an atom can be 100,000 times the size of its nucleus. To get a sense of the scale of an atom, look back at the answer you calculated if the nucleus were the size of a dime. An electron in your model atom could be more than 1,700 meters away!

All the atoms of a single element have the same number of protons. But different elements have different numbers of protons. For example, all hydrogen atoms have only one proton, and all carbon atoms have six protons. Atoms have no overall electric charge because each atom has the same number of electrons as protons. As you will read in Section 2, the number of electrons is key in explaining why different elements have different properties.

Reading Checkpoint **What are neutrons, and where in an atom are they found?**

FIGURE 7
Size of an Atom
If the nucleus of an atom were the size of a pencil eraser on home plate of this baseball field, its electrons could be farther away than the outfield.

Section 1 Assessment

Target Reading Skill **Outlining** Use the information in your outline about elements and atoms to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is matter? What is an element?
   b. **Explaining** Why are elements called the building blocks of matter?
   c. **Inferring** Water is a compound. Does water contain elements? Explain.
2. a. **Reviewing** In general, why did atomic theory change with time?
   b. **Describing** Describe Bohr's model of the atom. What specific information did Bohr contribute to scientists' understanding of the atom?
   c. **Comparing and Contrasting** How is the modern atomic model different from Bohr's model? Why did scientists revise Bohr's model?

Writing in Science

Persuasive Letter Write a letter that Thomson might have sent to another scientist explaining why an atom must contain positive charges as well as negative charges. The letter should also explain why Thomson proposed the atomic model that he did.