11

Introduction to Atoms

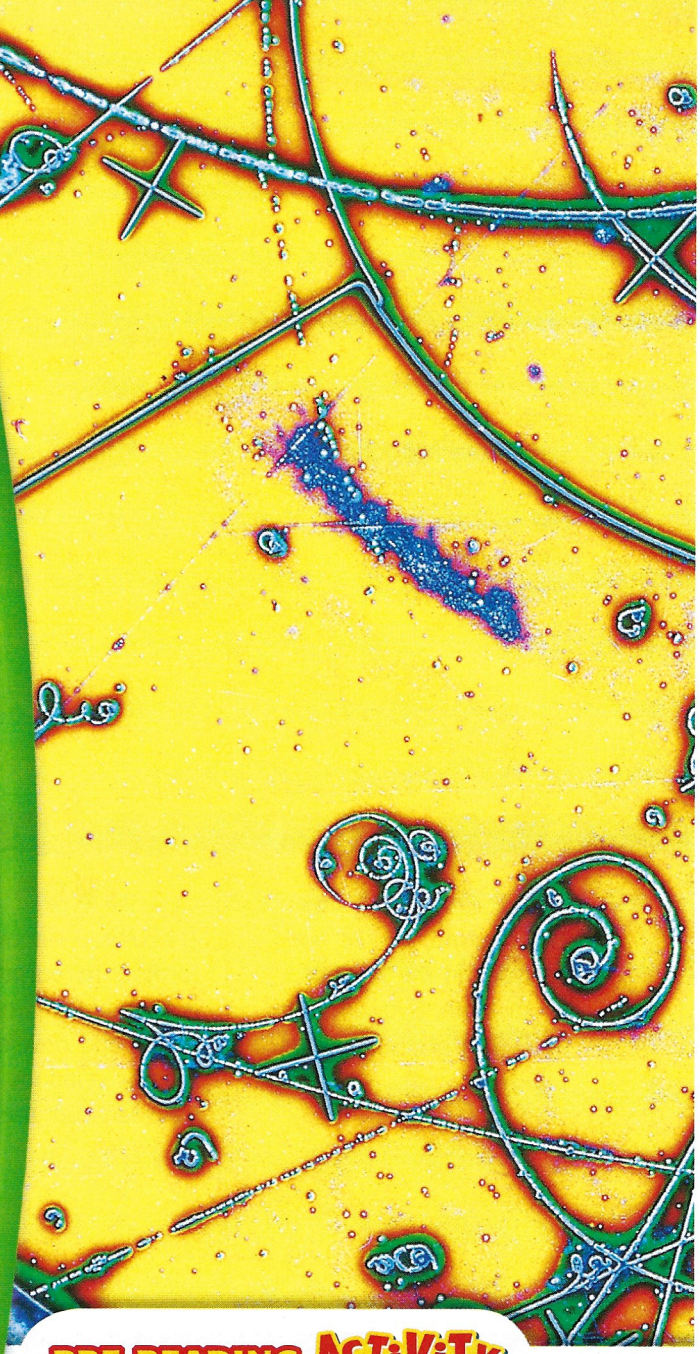
The Big Idea

Atoms are composed of small particles that determine the properties of the atom.

SECTION

About the PHOTO

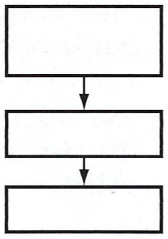
You have probably made bubbles with a plastic wand and a soapy liquid. Some scientists make bubbles by using a bubble chamber. A bubble chamber is filled with a pressurized liquid that forms bubbles when a charged particle moves through it. This photo shows the tracks made by charged particles moving through a bubble chamber. Bubble chambers help scientists learn about particles called *atoms,* which make up all objects.



PRE-READING ACTIVITY

Graphic Organizer

Chain-of-Events Chart Before you read the chapter, create the graphic organizer entitled "Chain-of-Events Chart" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the chart with details about each step in the historical development of ideas about atoms.



SECTION 1

Development of the Atomic Theory

Have you ever watched a mystery movie and thought you knew who the criminal was? Have you ever changed your mind because of a new fact or clue?

The same thing happens in science! Sometimes an idea or model must be changed as new information is gathered. In this section, you will see how our ideas about atoms have changed over time. Your first stop is ancient Greece.

What You Will Learn

- Describe some of the experiments that led to the current atomic theory.
- Compare the different models of the atom.
- Explain how the atomic theory has changed as scientists have discovered new information about the atom.

Vocabulary

atom
electron
nucleus
electron cloud

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

The Beginning of Atomic Theory

Imagine that you cut something in half. Then, you cut each half in half again, and so on. Could you keep cutting the pieces in half forever? Around 440 BCE, a Greek philosopher named Democritus (di MAHK ruh tuhs) thought that you would eventually end up with a particle that could not be cut. He called this particle an atom. The word *atom* is from the Greek word *atomos,* meaning "not able to be divided." Democritus said that all atoms are small, hard particles. He thought that atoms were made of a single material formed into different shapes and sizes.

From Aristotle to Modern Science

Aristotle (AR is TAHT'l), another Greek philosopher, disagreed with Democritus's ideas. He believed that you would never end up with a particle that could not be cut. He had such a strong influence on people's ideas that for a long time, most people thought he was right.

Democritus was right, though: Matter is made of particles, which we call atoms. An **atom** is the smallest particle into which an element can be divided and still be the same substance. **Figure 1** shows a picture of aluminum atoms taken with a scanning tunneling electron microscope (STM). Long before actually being able to scan atoms, scientists had ideas about them.

Figure 1 *Aluminum cans, like all matter, are made of atoms. Aluminum atoms can be seen here as an image from a scanning tunneling electron microscope.*

Dalton's Atomic Theory Based on Experiments

atom the smallest unit of an element that maintains the properties of that element

By the late 1700s, scientists had learned that elements combine in certain proportions based on mass to form compounds. For example, hydrogen and oxygen always combine in the same proportion to form water. John Dalton, a British chemist and schoolteacher, wanted to know why. He experimented with different substances. His results suggested that elements combine in certain proportions because they are made of single atoms. Dalton, shown in **Figure 2,** published his atomic theory in 1803. His theory stated the following ideas:

- All substances are made of atoms. Atoms are small particles that cannot be created, divided, or destroyed.
- Atoms of the same element are exactly alike, and atoms of different elements are different.
- Atoms join with other atoms to make new substances.

Reading Check **Why did Dalton think that elements are made of single atoms?** (*See the Appendix for answers to Reading Checks.*)

Not Quite Correct

Toward the end of the 1800s, scientists agreed that Dalton's theory explained much of what they saw. However, new information was found that did not fit some of Dalton's ideas. The atomic theory was then changed to describe the atom more correctly. As you read on, you will learn how Dalton's theory has changed, step by step, into the modern atomic theory.

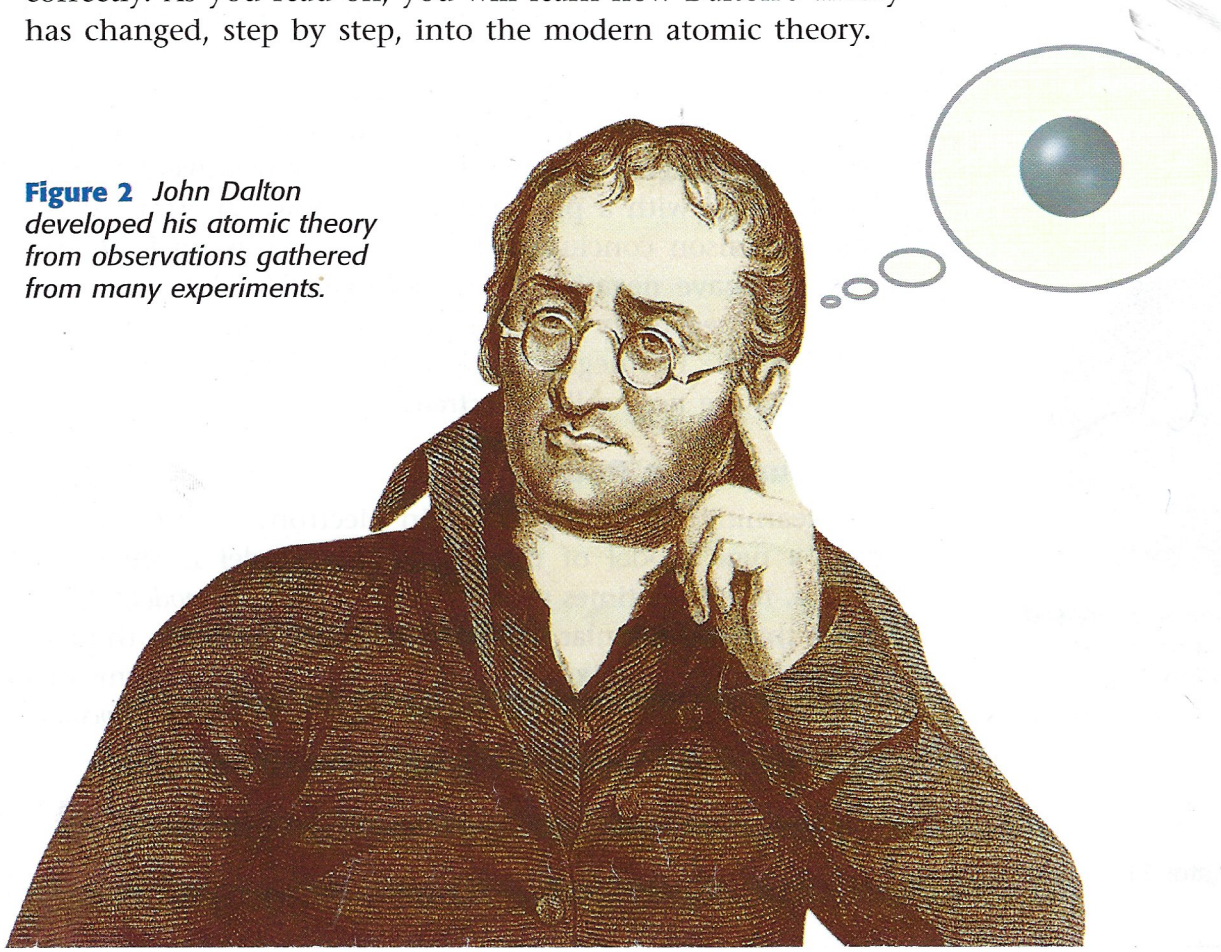
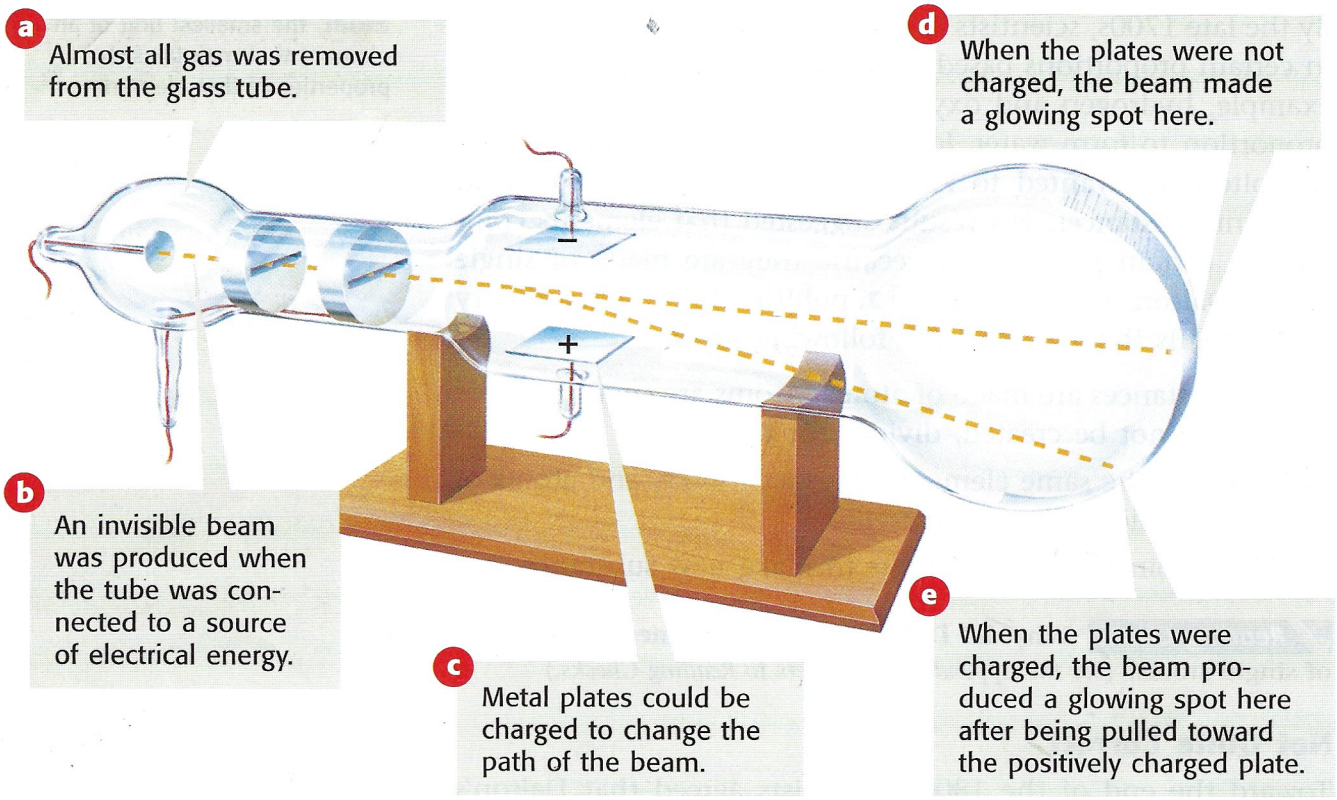


Figure 2 *John Dalton developed his atomic theory from observations gathered from many experiments.*

Figure 3 Thomson's Cathode-Ray Tube Experiment



Thomson's Discovery of Electrons

electron a subatomic particle that has a negative charge

In 1897, a British scientist named J. J. Thomson showed that there was a mistake in Dalton's theory. Thomson discovered that there are small particles *inside* the atom. This means that atoms can be divided into even smaller parts.

Thomson experimented with a cathode-ray tube like the one shown in **Figure 3.** He discovered that a positively charged plate (marked with a plus sign in the drawing) attracted the beam. Thomson concluded that the beam was made of particles that have negative electric charges. He also concluded that these negatively charged particles are present in every kind of atom. The negatively charged particles that Thomson discovered are now called **electrons.**

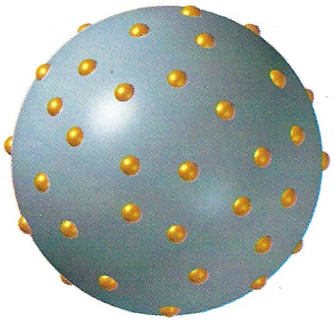


Figure 4 *Thomson proposed that electrons were located throughout an atom like plums in a pudding, as shown in this model.*

Like Plums in a Pudding

After learning that atoms contain electrons, Thomson proposed a new model of the atom. This model is shown in **Figure 4.** It is sometimes called the *plum-pudding model,* after a dessert that was popular in Thomson's day. Thomson thought that electrons were mixed throughout an atom, like plums in a pudding. Today, you might call Thomson's model the *chocolate chip ice-cream model.*

Rutherford's Atomic "Shooting Gallery"

In 1909, a former student of Thomson's named Ernest Rutherford decided to test Thomson's theory. He designed an experiment to study the parts of the atom. He aimed a beam of small, positively charged particles at a thin sheet of gold foil. **Figure 5** shows Rutherford's experiment. Rutherford put a special coating behind the foil. The coating glowed when hit by the positively charged particles. Rutherford could then see where the particles went after hitting the gold.

Reading Check **How could Rutherford tell where the positively charged particles went after hitting the gold foil?**

Surprising Results

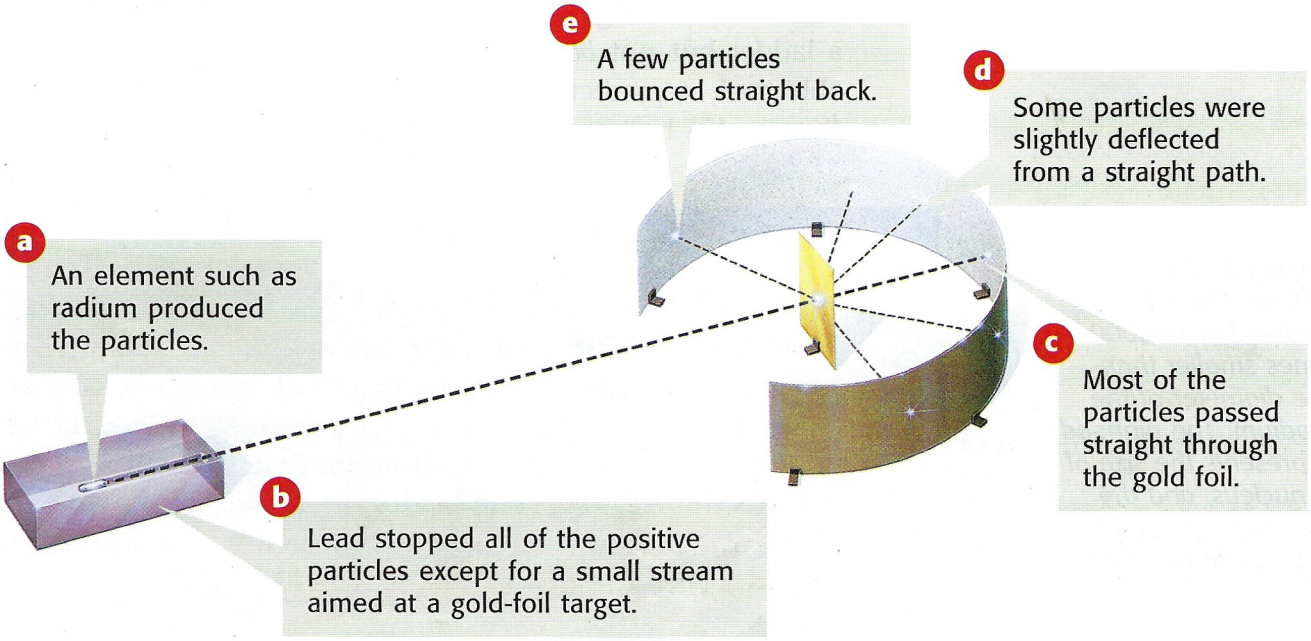
Rutherford started with Thomson's idea that atoms are soft "blobs" of matter. He expected the particles to pass right through the gold in a straight line. Most of the particles did just that. But to Rutherford's great surprise, some of the particles were deflected (turned to one side). Some even bounced straight back. Rutherford reportedly said,

"It was quite the most incredible event that has ever happened to me in my life. It was almost as if you fired a fifteen-inch shell into a piece of tissue paper and it came back and hit you."

CONNECTION TO Language Arts

WRITING SKILL **Solving Mysteries** Scientists who made discoveries about the atom had to do so by gathering clues and drawing conclusions from experiments. Read a short mystery story, and write a one-page paper in which you discuss the methods that were used to solve the mystery in the story. Compare these methods with those used by scientists finding out about what atoms are like.

Figure 5 **Rutherford's Gold-Foil Experiment**



nucleus in physical science, an atom's central region, which is made up of protons and neutrons

electron cloud a region around the nucleus of an atom where electrons are likely to be found

Where Are the Electrons?

The plum-pudding model of the atom did not explain what Rutherford saw. Most of the tiny particles went straight through the gold foil, with a small number being deflected. He realized that in order to explain this, atoms must be considered mostly empty space, with a tiny part made of highly dense matter.

Far from the Nucleus

In 1911, Rutherford revised the atomic theory. He made a new model of the atom, as shown in **Figure 6.** Rutherford proposed that in the center of the atom is a tiny, extremely dense, positively charged part called the **nucleus** (NOO klee uhs). Because like charges repel, Rutherford reasoned that positively charged particles that passed close by the nucleus were pushed away by the positive charges in the nucleus. A particle that headed straight for a nucleus would be pushed almost straight back in the direction from which it came. From his results, Rutherford calculated that the diameter of the nucleus was 100,000 times smaller than the diameter of the gold atom. To get an idea of this kind of difference in size, look at **Figure 7.**

Reading Check **How did Rutherford change Thomson's model of the atom?**

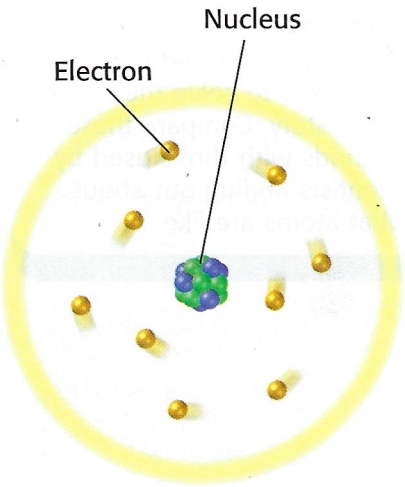


Figure 6 *Rutherford's model of the atom had electrons surrounding the nucleus at a distance. (This model does not show the true scale of sizes and distances.)*

Bohr's Electron Levels

In 1913, Niels Bohr, a Danish scientist who worked with Rutherford, studied the way that atoms react to light. Bohr's results led him to propose that electrons move around the nucleus in certain paths, or energy levels. In Bohr's model, there are no paths between the levels. But electrons can jump from a path in one level to a path in another level. Think of the levels as rungs on a ladder. You can stand on the rungs of a ladder but not *between* the rungs. Bohr's model was a valuable tool in predicting some atomic behavior, but the atomic theory still had room for improvement.

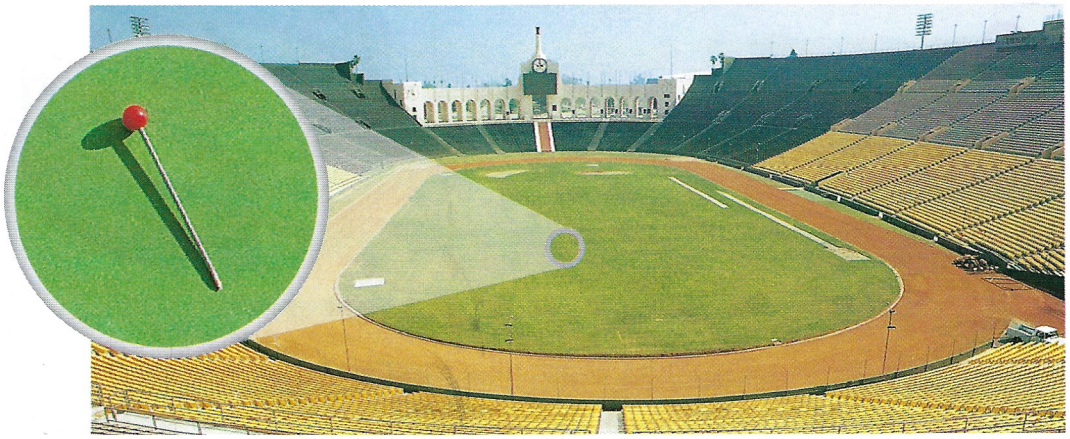


Figure 7 *The diameter of this pinhead is 100,000 times smaller than the diameter of the stadium. The pinhead represents the size of a nucleus, and the stadium represents the size of an atom.*

The Modern Atomic Theory

Many 20th-century scientists added to our current understanding of the atom. An Austrian physicist named Erwin Schrödinger (SHROH ding uhr) and a German physicist named Werner Heisenberg (HIE zuhn berkh) did especially important work. They further explained the nature of electrons in the atom. For example, electrons do not travel in definite paths as Bohr suggested. In fact, the exact path of an electron cannot be predicted. According to the current theory, there are regions inside the atom where electrons are *likely* to be found. These regions are called **electron clouds.** The electron-cloud model of the atom is shown in **Figure 8.**

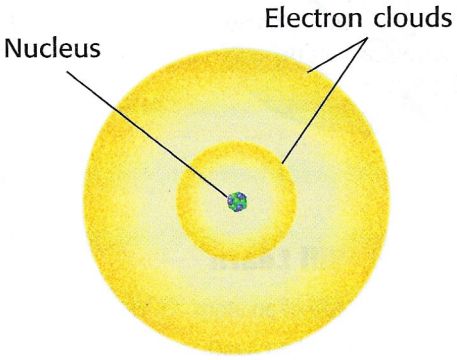


Figure 8 *In the current model of the atom, electrons surround the nucleus in electron clouds.*

SECTION Review

Summary

- Democritus thought that matter is composed of atoms.
- Dalton based his theory on observations of how elements combine.
- Thomson discovered electrons in atoms.
- Rutherford discovered that atoms are mostly empty space with a dense, positive nucleus.
- Bohr proposed that electrons are located in levels at certain distances from the nucleus.
- The electron-cloud model represents the current atomic theory.

Using Key Terms

1. In your own words, write a definition for the term *atom.*

The statements below are false. For each statement, replace the underlined term to make a true statement.

2. A <u>nucleus</u> is a particle with a negative electric charge.
3. The <u>electron</u> is where most of an atom's mass is located.

Understanding Key Ideas

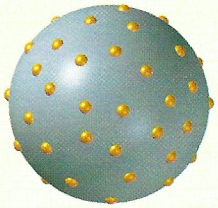
4. Which of the following scientists discovered that atoms contain electrons?
   - **a.** Dalton
   - **b.** Thomson
   - **c.** Rutherford
   - **d.** Bohr
5. What did Dalton do in developing his theory that Democritus did not do?
6. What discovery demonstrated that atoms are mostly empty space?
7. What refinements did Bohr make to Rutherford's proposed atomic theory?

Critical Thinking

8. **Making Comparisons** Compare the location of electrons in Bohr's theory with the location of electrons in the current atomic theory.
9. **Analyzing Methods** How does the design of Rutherford's experiment show what he was trying to find out?

Interpreting Graphics

10. What about the atomic model shown below was shown to be incorrect?



SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org
Topic: Development of the Atomic Theory; Current Atomic Theory
SciLinks code: HSM0399; HSM0371