Section 1 Introduction to Atoms

Objectives

After this lesson, students will be able to

K.3.1.1 Describe the structure of an atom.

K.3.1.2 Describe elements in terms of their atoms.

K.3.1.3 Explain how models are useful for understanding atoms.

Target Reading Skill

Previewing Visuals Explain that looking at the visuals before they read helps students activate prior knowledge and predict what they are about to read.

Answers

Sample questions and answers: **What particles are in the center of an atom?** *(Protons and neutrons)* **What particles move around the outside of the nucleus?** *(Electrons)*

All in One Teaching Resources

- Transparency K20

Preteach

Build Background Knowledge L2

Parts Make Up the Whole

Distribute hand lenses and sections from the Sunday newspaper comics. Have students examine the comics with the hand lenses and describe what they see. Ask: **How do the Sunday comics compare to the painting in Figure 1?** *(Both are made up of tiny dots of color.)* Explain that like these images, matter is made of tiny parts called atoms.

Section 1 Introduction to Atoms

Reading Preview

Key Concepts

- What is the structure of an atom?
- How are elements described in terms of their atoms?
- Why are models useful for understanding atoms?

Key Terms

- nucleus
- proton
- neutron
- electron
- atomic number
- isotope
- mass number
- model

Target Reading Skill

Previewing Visuals Before you read, preview Figure 2. Then write two questions you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Structure of an Atom

Q. What particles are in the center of an atom?
A.
Q.

Lab Zone Discover Activity

What's in the Box?

1. Your teacher will give you a sealed box that contains an object. Without opening the box, move the box around to find out as much as you can about the object.
2. Make a list of your observations about the object. For example, does the object slide or roll? Is it heavy or light? Is it soft or hard? Is the object round or flat?
3. Think about familiar objects that could give you clues about what's inside the box.

Think It Over

Inferring Make a sketch showing what you think the object looks like. Tell how you inferred the properties of the object from indirect observations.

Glance at the painting below and you see people enjoying an afternoon in the park. Now look closely at the circled detail of the painting. There you'll discover that the artist used thousands of small spots of color to create these images of people and the park.

Are you surprised that such a rich painting can be created from lots of small spots? Matter is like that, too. The properties of matter that you can observe result from the properties of tiny objects that you cannot see. As you learned in Chapter 1, the tiny objects that make up all matter are atoms.

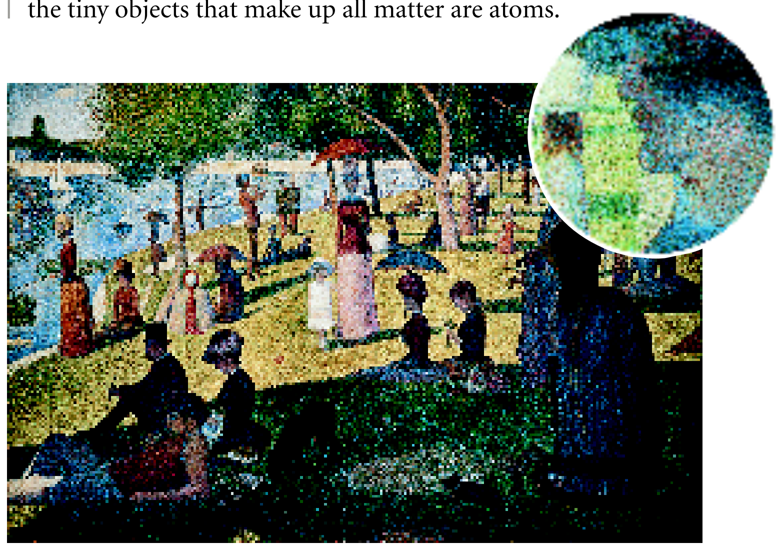

FIGURE 1
Sunday Afternoon on the Island of La Grande Jatte
This painting by artist Georges Seurat, which is made from tiny dots of paint, gives you a simple model for thinking about how matter is made of atoms.

Lab Zone Discover Activity

Skills Focus Inferring L2

Materials tape, shoe box, an object such as a pencil, empty soda can, sock, marble, or sponge

Time 10 minutes

Tips Have students bring shoe boxes from home. Place a different object in each shoebox and securely tape it closed. Emphasize that students are making indirect observations and may not draw precise conclusions.

Think It Over Students' sketches should be consistent with their observations, but may not be correct. Students should explain how their indirect observations led them to identify certain properties of the object. For example, a round object will roll and a soft object will make less sound when hitting the sides of the box.

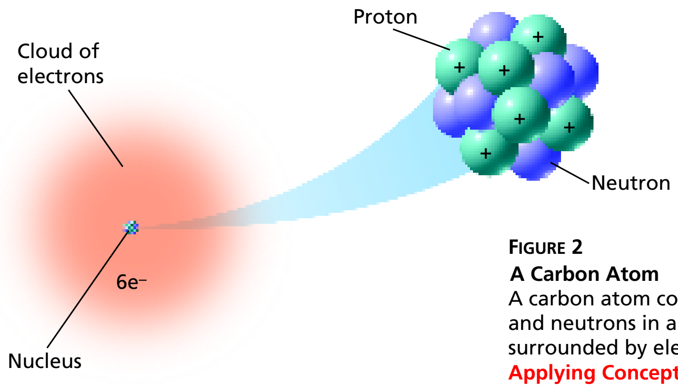

FIGURE 2
A Carbon Atom
A carbon atom consists of protons and neutrons in a nucleus that is surrounded by electrons.
Applying Concepts *What effect do the neutrons in the nucleus have on the atom's electric charge? Explain.*

Structure of an Atom

If you could look into a single atom, what might you see? Figuring out what atoms are made of hasn't been easy. Theories about their shape and structure have changed many times and continue to be improved even now. Until about 100 years ago, scientists thought atoms were the smallest particles of matter. Now, scientists know more. **Atoms are made of even smaller particles called protons, neutrons, and electrons.** Understanding the structure of atoms will help you understand the properties of matter.

Particles in Atoms An atom consists of a nucleus surrounded by one or more electrons. The **nucleus** (NOO klee us) (plural *nuclei*) is the very small center core of an atom. The nucleus is a group of smaller particles called protons and neutrons. **Protons** have a positive electric charge (indicated by a plus symbol, +). **Neutrons** have no charge. They are neutral. The third type of particle in an atom moves in the space outside the nucleus. **Electrons** move rapidly around the nucleus and have a negative electric charge. An electron is shown by the symbol e^-.

Look at the model of a carbon atom in Figure 2. If you count the number of protons and electrons, you'll see there are six of each. In an atom, the number of protons equals the number of electrons. As a result, the positive charge from the protons equals the negative charge from the electrons. The charges balance, making the atom neutral.

Reading Checkpoint **What kind of charge does a proton have?**

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Instruct

Structure of an Atom

Teach Key Concepts L2

Parts of an Atom

Focus Explain that all matter is made up of small particles called atoms.

Teach Diagram an atom on the board. Label the nucleus and electron cloud. Ask: **What particles of an atom are found in the nucleus?** *(Protons and neutrons)* **Where are electrons found?** *(In a cloud around the nucleus)* Add the symbols for the particles.

Apply Point out that protons have a positive electric charge, electrons are negative, and neutrons are neutral. Ask: **Why is the carbon atom in Figure 2 neutral?** *(The equal number of protons and electrons causes the positive and negative charges to cancel each other out.)* **learning modality: visual**

All in One **Teaching Resources**
- Transparency K21

Help Students Read L1

Vocabulary: Word Origin Explain that *atom* comes from the Greek word *atomos*, meaning "indivisible." Ask: **How is being indivisible related to the smallest unit of matter?** *(The atom is the smallest particle that matter can be broken into.)*

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Students can review atoms in an online activity.

Independent Practice L2

All in One **Teaching Resources**
- *Guided Reading and Study Worksheet: Introduction to Atoms*

Student Edition on Audio CD

Monitor Progress L2

Drawing Invite students to draw and label a diagram of an atom.

Students can save their diagrams in their portfolios. Portfolio

Answers

Figure 2 None; neutrons have no charge.

Reading Checkpoint A proton has a positive charge.

Differentiated Instruction

English Learners/Beginning L1

Vocabulary: Link to Visual Point to each label in Figure 2 and pronounce each word, including *atom*. Invite students to repeat each word. Give students cards with one word from the diagram on each. Cover the words in the diagram and have students match the word cards to the diagram. Correct pronunciations as needed. **learning modality: visual**

English Learners/Intermediate L2

Vocabulary: Link to Visual Have students do the activity described at left without word cards. Also, add the words *positive charge*, *negative charge*, and *no charge* and have students match the particle to its charge. **learning modality: visual**

Build Inquiry L2

Modeling Atomic Structure

Materials apron, beads in two colors, glue, disposable gloves, newspapers, large sheet of plain paper, tape, old toothbrush, water in disposable container, watercolor paint

Time 15 minutes

Focus Ask: **Can you see an atom?** *(No, atoms are too small.)* **Why is it useful to model an atom?** *(Sample answer: To learn about its structure and properties)*

Teach Students can choose different-colored beads for the protons and neutrons. Have students glue these in the center of the paper for the nucleus. Students may choose as many protons and neutrons as they wish. Students can model the electron cloud by dipping the toothbrush in paint and flicking the bristles over the top of the paper in a large circle around the nucleus. (Tape newspapers to the work surface.)

Apply Ask: **If your atom is neutral, how many electrons does it have?** *(The same number as the number of protons)* **Why are the electrons shown as a cloud?** *(The electrons move all the time and may be anywhere within the space shown by the cloud.)* **learning modality: kinesthetic**

Build Inquiry L2

Making Analogies About Atomic Particles

Time 15 minutes

Focus Tell students that an analogy makes an abstract idea easier to understand.

Teach Ask: **Which is easier to understand—the mass of an elephant compared to the mass of a cat or saying that a proton has 2,000 times more mass than an electron?** *(The elephant and the cat)* Explain that, like the proton, the elephant (about 8,000 kg) has 2,000 times more mass than the cat (about 4 kg). Challenge student groups to develop their own analogies.

Apply Ask: **Does your analogy also reflect the larger volume held by the electrons?** (In most student analogies, the larger mass will also have the larger volume.) Challenge students to develop an analogy to compare the volumes of the nucleus and electron cloud. **learning modality: logical/ mathematical**

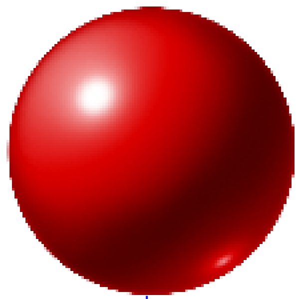
A Cloud of Electrons Electrons move within a sphere-shaped region surrounding the nucleus. Scientists depict this region as a cloud of negative charge because electrons may be anywhere within it. Electrons with lower energy usually move in the space near the atom's nucleus. Electrons with higher energy move within the space farther from the nucleus.

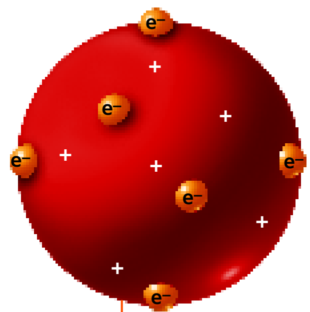
Most of an atom's volume is the space in which electrons move. That space is huge compared to the space taken up by the nucleus. To picture the difference, imagine holding a pencil while standing at the pitcher's mound in a baseball stadium. If the nucleus were the size of the pencil's eraser, the electrons could be as far away as the top row of seats!

Science and History

Models of Atoms

For over two centuries, scientists have created models of atoms in an effort to understand why matter behaves as it does. As scientists have learned more, the model of the atom has changed.





1808
Dalton Model
British chemist John Dalton concluded that each element is made of atoms that are all alike. He also thought that different elements have atoms of different mass. Dalton imagined atoms as tiny, solid balls.

1897
Thomson Model
British scientist J.J. Thomson discovered the electron. He later proposed a new model, suggesting that an atom is a positively charged sphere with electrons embedded in it. His model could be described as looking like a muffin with berries or raisins scattered through it.

1904
Nagaoka Model
Japanese physicist Hantaro Nagaoka proposed a model of the atom that had a large sphere in the center with a positive charge. His model showed the electrons revolving around this sphere like the planets around the sun.

1800 | 1850 | 1875 | 1900

Background

Facts and Figures Chemistry books often show electrons as they are in Bohr's atomic model, because the grouping of electrons in orbital shells helps explain the reactivity of atoms. It is the electrons in the outer shell of the atom that are gained, lost, or shared when an atom of one element reacts with the atom of another element. Using the Bohr model helps chemists describe the formation of chemical bonds.

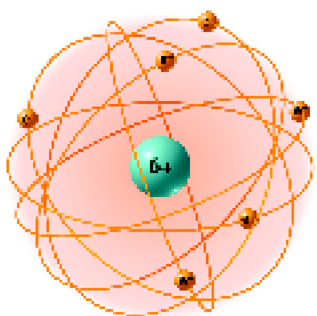
The current atomic model is very similar to the one proposed in the 1920s. The refinements of the model have affected the structure of the nucleus. Subatomic particles, called quarks, make up protons and neutrons. The force that holds these subatomic particles together comes from other particles called gluons.

Comparing Particle Masses Although electrons occupy most of an atom's volume, they don't account for much of its mass. It takes almost 2,000 electrons to equal the mass of just one proton. On the other hand, a proton and a neutron are about equal in mass. Together, the protons and neutrons make up nearly all the mass of an atom.

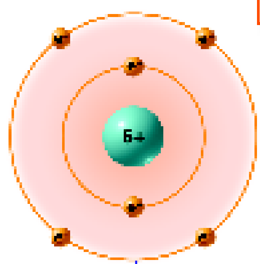
Atoms are too small to be measured in everyday units of mass, such as grams or kilograms. Instead, scientists use units known as atomic mass units (amu). A proton or a neutron has a mass equal to about one amu. The mass of an electron is about 1/2,000 amu.

Writing in Science

Research and Write Find out more about one of the scientists who worked on models of the atom. Write an imaginary interview with this person in which you discuss his work with him.

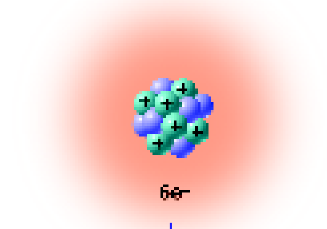


1911 Rutherford Model
British physicist Ernest Rutherford concluded that the atom is mostly empty space. Electrons orbit randomly around a small, positively charged nucleus.

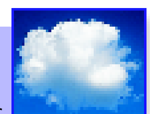


1913 Bohr Model
Danish physicist Niels Bohr proposed a model that showed electrons moving in specific layers, or shells, rather than randomly. He said that atoms absorb or give off energy when the electrons move from one shell to another.

1932 Chadwick Model
British physicist James Chadwick discovered the neutron. The existence of neutrons explained why atoms were heavier than the total mass of their protons and electrons.



The Present Modern Model
The current atomic model results from work done from the 1920s to the present. Electrons form a negatively charged cloud around the nucleus. It is impossible to determine exactly where an electron is at a given time.



1925 1950 1975 2000

Science and History

Focus Tell students that the first atomic model was proposed almost 200 years ago. A few years before this, in 1806, Lewis and Clark returned from exploring the Louisiana Territory. Also point out that the existence of neutrons was not discovered until the era of the Great Depression, a few years before World War II.

Teach Invite students to compare and contrast the atomic models diagrammed in the timeline. Ask: **What was one of the first theories about atomic structure that has stood the test of time?** *(Sample answer: The positive charge is located in the center of the atom.)* **How has the position of electrons changed over time?** *(Sample answer: The electrons moved from being embedded in the sphere to moving randomly about the nucleus to moving in specific layers to being impossible to locate at any given time.)*

Writing in Science

Writing Mode Research

Scoring Rubric

4 Exceeds criteria; includes a lively and imaginative interview with insightful questions and accurate and complete answers that reflect the life of the scientist
3 Meets criteria
2 Includes only brief but accurate information
1 Includes some incorrect and/or incomplete information

Differentiated Instruction

Special Needs L1

Classifying Atomic Particles Give students two types of balls that differ in mass but are similar in size, such as marbles and foam balls. Invite students to choose a ball to represent a proton. Repeat for a neutron and an electron. (The heavier balls would be protons and neutrons; lighter ones, electrons.) **learning modality: kinesthetic**

Gifted and Talented L3

Researching Quarks Tell students that protons and neutrons are made up of even smaller particles called quarks. Encourage students to use Internet sources to find out about these subatomic particles. Students can prepare a poster to share what they learned with the class. **learning modality: logical/mathematical**

Monitor Progress L2

Skills Check Have students develop a table in which they compare and contrast the mass and volume of protons, neutrons, and electrons.

Atoms and Elements

Teach Key Concepts L2

Atoms Are Specific to Elements

Focus Remind students that an element is a pure substance.

Teach Explain that each element is made of atoms that are different from the atoms of other elements. Ask: **How do atoms of one element differ from those of another element?** *(In their number of protons)* Diagram the atomic nuclei of three different elements. Have students count the number of protons in each. Explain that the number of protons is the element's atomic number.

Apply Ask: **What does mass number equal?** *(The sum of protons and neutrons)* **learning modality: visual**

All in One Teaching Resources

- Transparency K22

Address Misconceptions L2

Many Different Particles

Focus Students may confuse the particles that make up elements and the particles that make up atoms.

Teach Remind students that elements are a kind of matter. Ask: **What are the particles that make up elements and compounds?** *(Atoms)* Point out that an atom is the smallest particle of an element. Ask: **What particles make up an atom?** *(Protons, neutrons, and electrons)*

Apply Ask: **What would happen if protons were added to an atom?** *(The atom becomes a different element.)* **learning modality: verbal**

Modeling Atoms

Teach Key Concepts L2

Usefulness of Scientific Models

Focus Ask: **How can you guess what is inside a sealed box?** *(Sample answer: By making observations that don't depend on seeing what's inside the box)*

Teach Ask: **Why is it difficult for scientists to study atoms?** *(Atoms are too small to be seen, even by powerful microscopes.)* **Why is it helpful for scientists to use models to study atoms?** *(Scientists make predictions and test the models to see if the atoms behave as predicted.)*

Apply Ask: **Once scientists develop a model, can they change it?** *(Yes, as they get more observations from testing)* **learning modality: verbal**

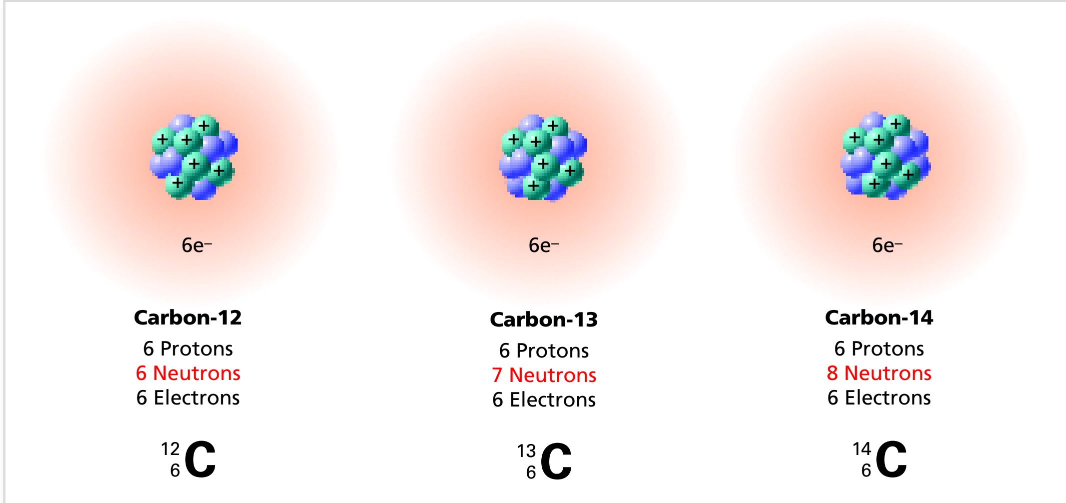


FIGURE 3
Isotopes
Atoms of all isotopes of carbon contain 6 protons, but they differ in their number of neutrons. Carbon-12 is the most common isotope. **Interpreting Diagrams** *Which isotope of carbon has the largest mass number?*

Atoms and Elements

Each element consists of atoms that differ from the atoms of all other elements. **An element can be identified by the number of protons in the nucleus of its atoms.**

Atomic Number Every atom of an element has the same number of protons. For example, the nucleus of every carbon atom contains 6 protons. Every oxygen atom has 8 protons, and every iron atom has 26 protons. Each element has a unique **atomic number**—the number of protons in its nucleus. Carbon's atomic number is 6, oxygen's is 8, and iron's is 26.

Isotopes Although all atoms of an element have the same number of protons, their number of neutrons can vary. Atoms with the same number of protons and a different number of neutrons are called **isotopes** (EYE suh tohps). Three isotopes of carbon are illustrated in Figure 3. Each carbon atom has 6 protons, but you can see that the number of neutrons is 6, 7, or 8.

An isotope is identified by its **mass number,** which is the sum of the protons and neutrons in the nucleus of an atom. The most common isotope of carbon has a mass number of 12 (6 protons + 6 neutrons) and may be written as "carbon-12." Two other isotopes are carbon-13 and carbon-14. As shown in Figure 3, a symbol with the mass number above and the atomic number below may also be used to represent an isotope. Although these carbon atoms have different mass numbers, all carbon atoms react the same way chemically.

Modeling Atoms

Atoms are hard to study because they are amazingly small. The smallest visible speck of dust may contain 10 million billion atoms! Even a sheet of paper is about 10,000 atoms thick. Powerful microscopes can give a glimpse of atoms, such as the one shown in Figure 4. But they do not show the structure of atoms or how they might work.

Because atoms are so small, scientists create models to describe them. In science, a **model** may be a diagram, a mental picture, a mathematical statement, or an object that helps explain ideas about the natural world. Scientists use models to study objects and events that are too small, too large, too slow, too fast, too dangerous, or too far away to see. These models are used to make and test predictions. For example, you may know that engineers use crash-test dummies to test the safety of new car designs. The dummies serve as models for live human beings. In chemistry, models of atoms are used to explain how matter behaves. The modern atomic model explains why most elements react with other elements, while a few elements hardly react at all.

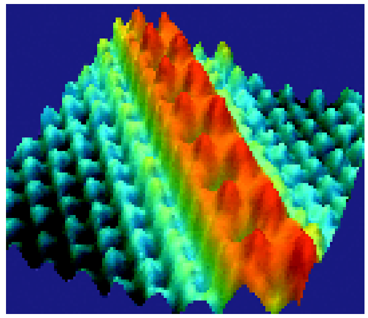


FIGURE 4
Imaging Atoms
This image was made by a scanning tunneling microscope. It shows a zigzag chain of cesium atoms (red) on a background of gallium and arsenic atoms (blue). The colors were added to the image.

Reading Checkpoint **What are three types of situations for which models can be useful?**

Section 1 Assessment

Target Reading Skill **Previewing Visuals** Compare your questions and answers about Figure 2 with those of a partner.

Reviewing Key Concepts

1. a. **Reviewing** What are the three main particles in an atom?
   b. **Comparing and Contrasting** How do the particles of an atom differ in electric charge?
   c. **Relating Cause and Effect** Why do atoms have no electric charge even though most of their particles have charges?
2. a. **Defining** What is the atomic number of an element?
   b. **Explaining** How can atomic numbers be used to distinguish one element from another?
   c. **Applying Concepts** The atomic number of the isotope nitrogen-15 is 7. How many protons, neutrons, and electrons make up an atom of nitrogen-15?
3. a. **Reviewing** What is the main reason that scientists use models to study atoms?
   b. **Making Generalizations** What kind of information do scientists seek when using models to study atoms?

Lab zone At-Home Activity

Modeling Atoms Build a three-dimensional model of an atom to show to your family. The model could be made of beads, cotton, small candies, clay, plastic foam, and other simple materials. Describe how the mass of the nucleus compares to the mass of the electrons. Explain what makes atoms of different elements different from one another. Emphasize that everything in your home is made of atoms in different combinations.

Lab zone At-Home Activity

Modeling Atoms L2 Consider displaying several three-dimensional atomic models made of household materials to give students some ideas. Students might explain that the mass of the nucleus makes up nearly the entire mass of the atom and that atoms of different elements have different numbers of protons.

Monitor Progress L2

Answers

Figure 3 Carbon-14

Reading Checkpoint Sample answer: When objects or events are too small, too large, too slow, too fast, too dangerous, or too far away to see.

Assess

Reviewing Key Concepts

1. a. Protons, neutrons, and electrons **b.** Proton—positive charge; neutron—no charge; electron—negative charge **c.** Each atom has equal numbers of positively charged protons and negatively charged electrons.

2. a. The number of protons in each atom of that element **b.** Each element has a unique atomic number because all atoms of that element have the same number of protons. **c.** Each atom of nitrogen-15 contains 7 protons, 8 neutrons, and 7 electrons.

3. a. Atoms are too small to be seen. **b.** To describe the structure of atoms and explain how matter behaves

Reteach L1

Help students draw a concept map that shows elements as types of matter and the atom as the smallest particle of an element. Also show that atoms are composed of protons and neutrons in a nucleus with electrons in an electron cloud.

Performance Assessment L2

Writing Have students write a description of the model used to describe atoms. Also have them describe why scientists use this model.

All in One Teaching Resources

- Section Summary: *Introduction to Atoms*
- Review and Reinforce: *Introduction to Atoms*
- Enrich: *Introduction to Atoms*