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.

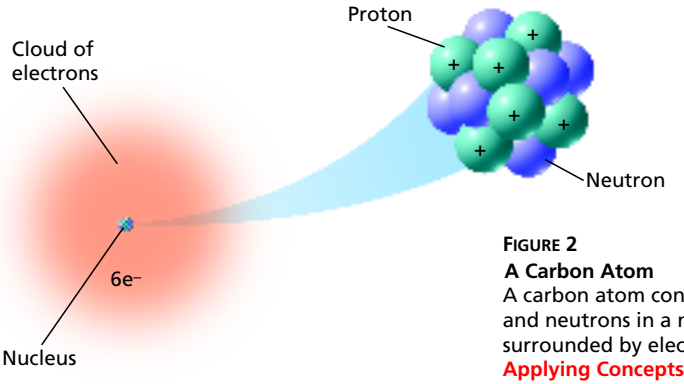


FIGURE 2
A Carbon Atom
A carbon atom consists of protons and neutrons in a nucleus that is surrounded by electrons.
Applying Concepts *What effect do the neutrons in the nucleus have on the atom's electric charge? Explain.*

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?**

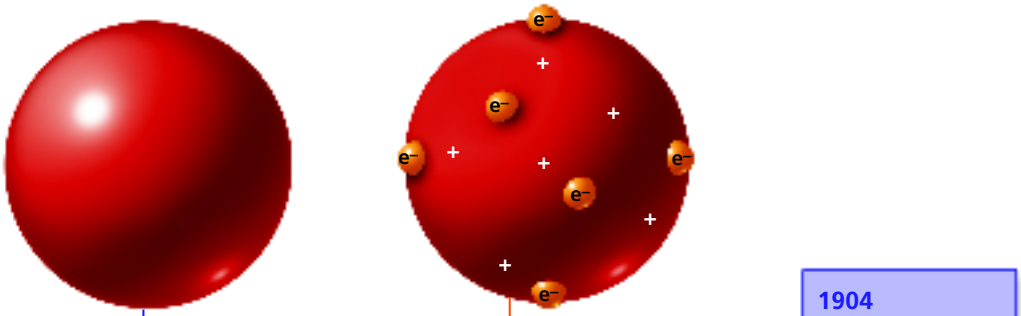
A Cloud of Electrons Electrons move within a sphere-shaped region surrounding the nucleus. Scientists depict this region as a cloud of negative charge because electrons may be anywhere within it. Electrons with lower energy usually move in the space near the atom's nucleus. Electrons with higher energy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

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.

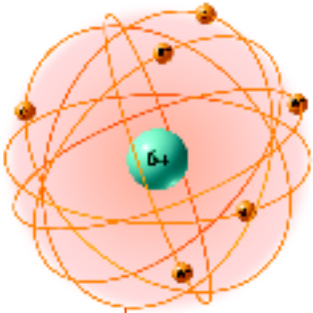
Atoms are too small to be measured in everyday units of mass, such as grams or kilograms. Instead, scientists use units known as atomic mass units (amu). A proton or a neutron has a mass equal to about one amu. The mass of an electron is about 1/2,000 amu.

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.

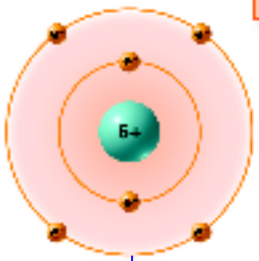
1932 Chadwick Model

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.



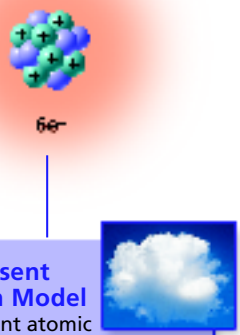
1911 Rutherford Model

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.



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

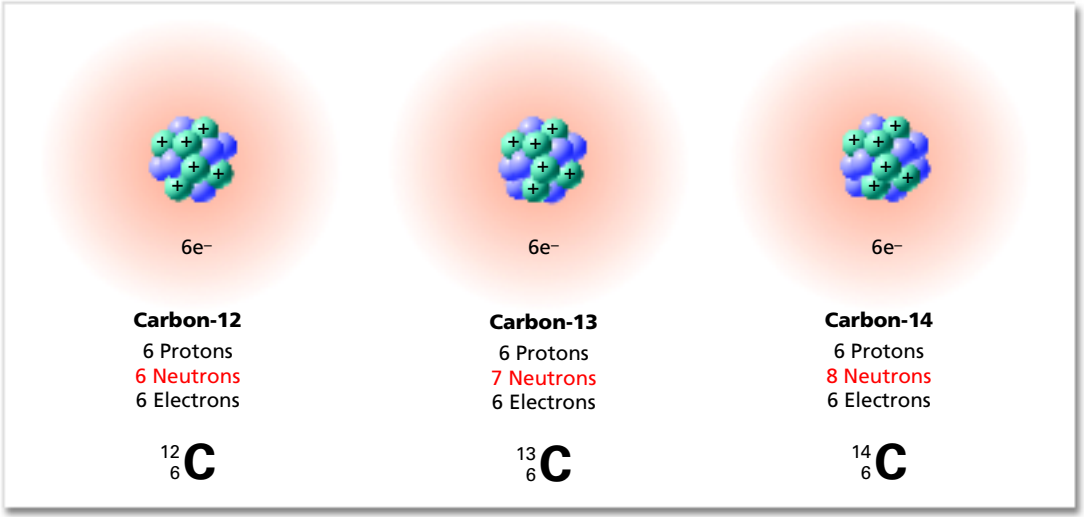


FIGURE 3
Isotopes
Atoms of all isotopes of carbon contain 6 protons, but they differ in their number of neutrons. Carbon-12 is the most common isotope. **Interpreting Diagrams** *Which isotope of carbon has the largest mass number?*

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.

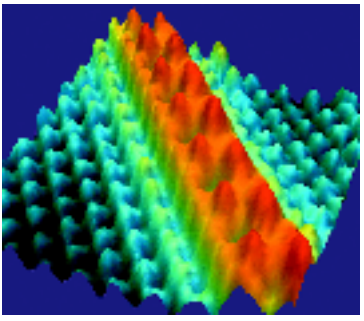


FIGURE 4
Imaging Atoms
This image was made by a scanning tunneling microscope. It shows a zigzag chain of cesium atoms (red) on a background of gallium and arsenic atoms (blue). The colors were added to the image.

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.