section 1

Atoms

as you read

What You'll Learn

- **Identify** the states of matter.
- **Describe** the internal structure of an atom.
- **Compare** isotopes of an element.

Why It's Important

Nearly everything around you—air, water, food, and clothes—is made of atoms.

Review Vocabulary

mass: amount of matter in an object

New Vocabulary

- matter
- atom
- element
- proton
- neutron
- electron
- atomic number
- mass number
- isotope

The Building Blocks of Matter

What do the objects you see, the air you breathe, and the food you eat have in common? They are matter. **Matter** is anything that has mass and takes up space. Heat and light are not matter, because they have no mass and do not take up space. Glance around the room. If all the objects you see are matter, why do they look so different from one another?

Atoms Matter, in its various forms, surrounds you. You can't see all matter as clearly as you see water, which is a transparent liquid, or rocks, which are colorful solids. You can't see air, for example, because air is colorless gases. The forms or properties of one type of matter differ from those of another type because matter is made up of tiny particles called **atoms.** The structures of different types of atoms and how they join together determine all the properties of matter that you can observe. **Figure 1** illustrates how small objects, like atoms, can be put together in different ways.

This figure shows only two types of atoms represented by the two colors. In reality, there are over 90 types of atoms having different sizes, making great variety possible.

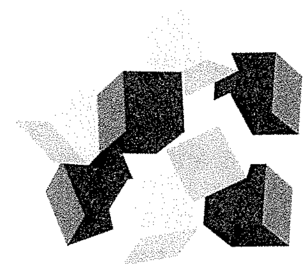
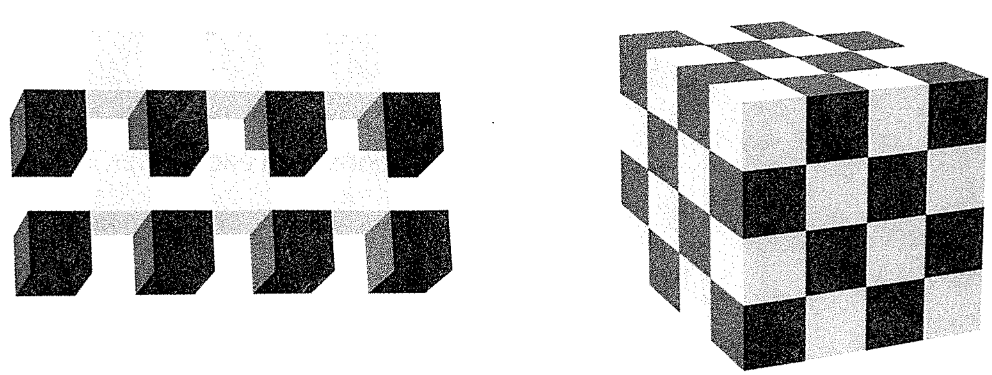


Figure 1 Like atoms, the same few blocks can combine in many ways.
Infer *How could this model help explain the variety of matter?*



The Structure of Matter Matter is joined together much like the blocks shown in **Figure 1.** The building blocks of matter are atoms. The types of atoms in matter and how they attach to each other give matter its properties.

Elements When atoms combine, they form many different types of matter. Your body contains several types of atoms combined in different ways. These atoms form the proteins, DNA, tissues, and other matter that make you the person you are. Most other objects that you see also are made of several different types of atoms. However, some substances are made of only one type of atom. **Elements** are substances that are made of only one type of atom and cannot be broken down into simpler substances by normal chemical or physical means.

Elements combine to make a variety of items you depend on every day. They also combine to make up the minerals that compose Earth's crust. Minerals usually are combinations of atoms that occur in nature as solid crystals and are usually found as mixtures in ores. Some minerals, however, are made up of only one element. These minerals, which include copper and silver, are called native elements. **Table 1** shows some common elements and their uses. A table of the elements, called the periodic table of the elements, is included on the inside back cover of this book.

Mini LAB

Searching for Elements

Procedure

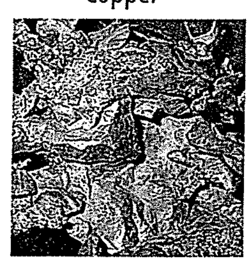
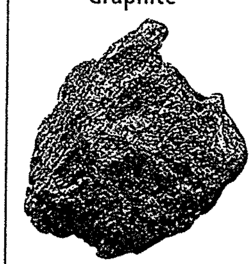
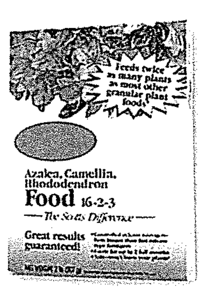
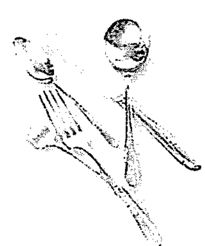
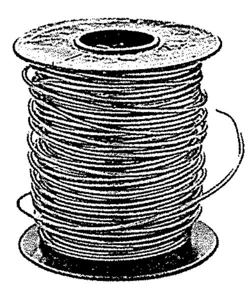
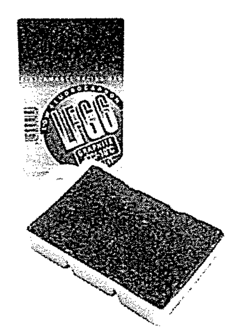
1. Obtain a copy of the **periodic table of the elements** and familiarize yourself with the elements.
2. Search your house for items made of various elements.
3. Use a **highlighter** to highlight the elements you discover on your copy of the periodic table.

Analysis

1. Were certain types of elements more common?
2. Infer why you did not find many of the elements.

Try at Home

Table 1 Some Common Uses of Elements

Element	Phosphorus	Silver	Copper	Carbon
Native state of the element	Phosphorus 	Silver 	Copper 	Graphite 
Uses of the element	Fertilizer 	Tableware 	Wire 	Ski wax 

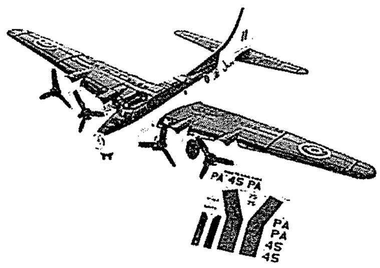


Figure 2 This model airplane is a small-scale version of a large object.

Modeling the Atom

How can you study things that are too small to be seen with the unaided eye? When something is too large or too small to observe directly, models can be used. The model airplane, shown in **Figure 2,** is a small version of a larger object. A model also can describe tiny objects, such as atoms, that otherwise are difficult or impossible to see.

The History of the Atomic Model More than 2,300 years ago, the Greek philosopher Democritus (dih MAH kruh tuss) proposed that matter is composed of small particles. He called these particles atoms and said that different types of matter were composed of different types of atoms. More than 2,000 years later, John Dalton expanded on these ideas. He theorized that all atoms of an element contain the same type of atom.

Protons and Neutrons In the early 1900s, additional work led to the development of the current model of the atom, shown in **Figure 3.** Three basic particles make up an atom—protons, neutrons (NOO trahnz), and electrons. **Protons** are particles that have a positive electric charge. **Neutrons** have no electric charge. Both particles are located in the nucleus—the center of an atom. With no negative charge to balance the positive charge of the protons, the charge of the nucleus is positive.

Electrons Particles with a negative charge are called **electrons,** and they exist outside of the nucleus. In 1913, Niels Bohr, a Danish scientist, proposed that an atom's electrons travel in orbitlike paths around the nucleus. He also proposed that electrons in an atom have energy that depends on their distance from the nucleus. Electrons in paths that are closer to the nucleus have lower energy, and electrons farther from the nucleus have higher energy.

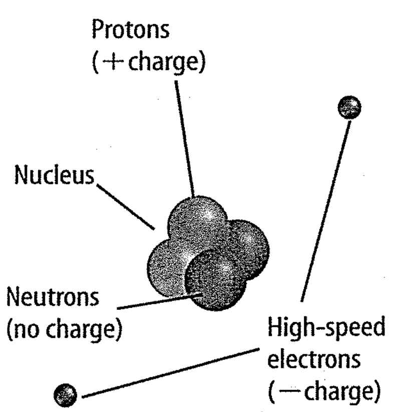


Figure 3 This model of a helium atom shows two protons and two neutrons in the nucleus, and two electrons in the electron cloud.

The Current Atomic Model Over the next several decades, research showed that electrons can be grouped into energy levels, each holding only a specific number of electrons. Also, electrons do not travel in orbitlike paths. Instead, scientists use a model that resembles a cloud surrounding the nucleus. Electrons can be anywhere within the cloud, but evidence suggests that they are located near the nucleus most of the time. To understand how this might work, imagine a beehive. The hive represents the nucleus of an atom. The bees swarming around the hive are like electrons moving around the nucleus. As they swarm, you can't predict their exact location, but they usually stay close to the hive.

Counting Atomic Particles

You now know where protons, neutrons, and electrons are located, but how many of each are in an atom? The number of protons in an atom depends on the element. All atoms of the same element have the same number of protons. For example, all iron atoms—whether in train tracks or breakfast cereal—contain 26 protons, and all atoms with 26 protons are iron atoms. The number of protons in an atom is equal to the **atomic number** of the element. This number can be found above the element symbol on the periodic table that is printed in the back of this book. Notice that as you go from left to right on the periodic table, the atomic number of the element increases by one.

INTEGRATE Health

Isotopes Some isotopes of elements are radioactive. Physicians can introduce these isotopes into a patient's circulatory system. The low-level radiation they emit allows the isotopes to be tracked as they move throughout the patient's body. Explain how this would be helpful in diagnosing a disease.

How many electrons? In a neutral atom, the number of protons is equal to the number of electrons. This makes the overall charge of the atom zero. Therefore, for a neutral atom:

Atomic number = number of protons = number of electrons

Atoms of an element can lose or gain electrons and still be the same element. When this happens, the atom is no longer neutral. Atoms with fewer electrons than protons have a positive charge, and atoms with more electrons than protons have a negative charge.

How many neutrons? Unlike protons, atoms of the same element can have different numbers of neutrons. The number of neutrons in an atom isn't found on the periodic table. Instead, you need to be given the atom's mass number. The **mass number** of an atom is equal to the number of protons plus the number of neutrons. The number of neutrons is determined by subtracting the atomic number from the mass number. For example, if the mass number of nitrogen is 14, subtracting its atomic number, seven, tells you that nitrogen has seven neutrons. In **Figure 4,** the number of neutrons can be determined by counting the blue spheres and the number of protons by counting orange spheres. Atoms of the same element that have different numbers of neutrons are called **isotopes. Table 2** lists useful isotopes of some elements.

Reading Check *How are isotopes of the same element different?*

Figure 4 This radioactive carbon atom is found in organic material.
Determine *this atom's mass number.*

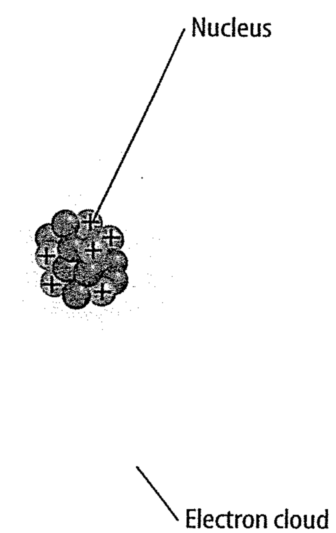


Table 2 Some Useful Isotopes

Isotope	Number of Protons	Number of Neutrons	Number of Electrons	Atomic Number	Mass Number
Hydrogen-1	1	0	1	1	1
Hydrogen-2	1	1	1	1	2
Hydrogen-3	1	2	1	1	3
Carbon-12	6	6	6	6	12
Carbon-14	6	8	6	6	14

Uses of Isotopes Scientists have found uses for isotopes that benefit humans. For example, medical doctors use radioactive isotopes to treat certain types of cancer, such as prostate cancer. Geologists use isotopes to date some rocks and fossils.

section 1 review

Summary

The Building Blocks of Matter

- Matter has mass and takes up space.
- Matter is made of particles called atoms.
- Elements are substances that are made of only one type of atom.

Modeling the Atom

- The current model of an atom includes protons, neutrons, and electrons.
- Protons and neutrons are found in the nucleus. Protons have a positive charge and neutrons are neutral. Electrons are located around the nucleus and have a negative charge.

Counting Atomic Particles

- The atomic number of an element equals the number of protons in an atom.
- The mass number of an element equals the number of protons plus the number of neutrons in an atom.
- Atoms of the same element having different numbers of neutrons are called isotopes.

Self Check

1. **Explain** how the air you breathe fits the definition of matter.
2. **Explain** why it is helpful to have a model of an atom.
3. **Determine** the charge of an atom that has five protons and five electons.
4. **Explain** how isotopes can be used to benefit humans.
5. **Think Critically** Oxygen-16 and oxygen-17 are isotopes of oxygen. The numbers 16 and 17 represent their mass numbers, respectively. If the element oxygen has an atomic number of 8, how many protons and neutrons are in these two isotopes?

Applying Math

6. **Use Numbers** If a sodium atom has 11 protons and 12 neutrons, what is its mass number?
7. **Simple Equations** The mass number of a nitrogen atom is 14. Find its atomic number in the periodic table shown on the inside back cover of this book. Then determine the number of neutrons in its nucleus.

Science Online earth.msscience.com/self_check_quiz

section 2

Combinations of Atoms

Interactions of Atoms

When you take a shower, eat your lunch, or do your homework on the computer, you probably don't think about elements. But everything you touch, eat, or use is made from them. Elements are all around you and in you.

There are about 90 naturally occurring elements on Earth. When you think about the variety of matter in the universe, you might find it difficult to believe that most of it consists of combinations of these same elements. How could so few elements produce so many different things? This happens because elements can combine in countless ways. For example, the same oxygen atoms that you breathe also might be found in many other objects, as shown in **Figure 5.** As you can see, each combination of atoms is unique. How do these combinations form and what holds them together?

as you read

What You'll Learn

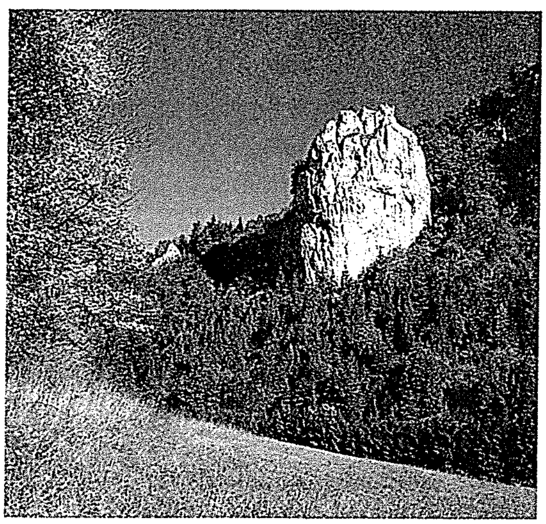
- **Describe** ways atoms combine to form compounds.
- **List** differences between compounds and mixtures.

Why It's Important

On Earth, most matter exists as compounds or mixtures.

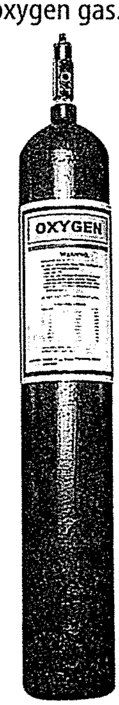
Review Vocabulary
force: a push or a pull

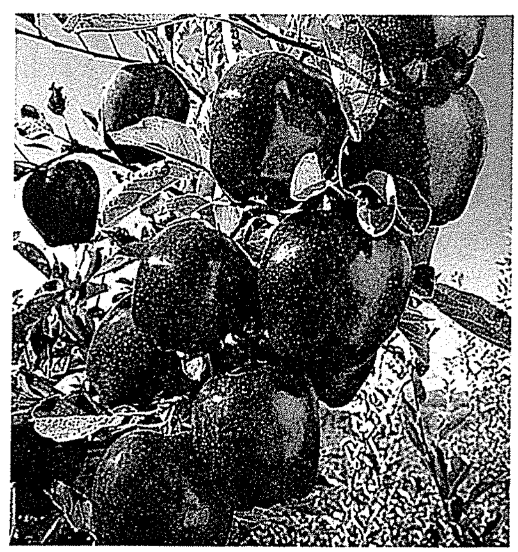
New Vocabulary
- compound
- molecule
- ion
- mixture
- heterogeneous mixture
- homogeneous mixture
- solution



Solid limestone has oxygen within its structure.

This canister contains pure oxygen gas.





Oxygen also is present in the juices of these apples.

Figure 5 Oxygen is a common element found in many different solids, liquids, and gases.
Infer *How can the same element, made from the same type of atoms, be found in so many different materials?*

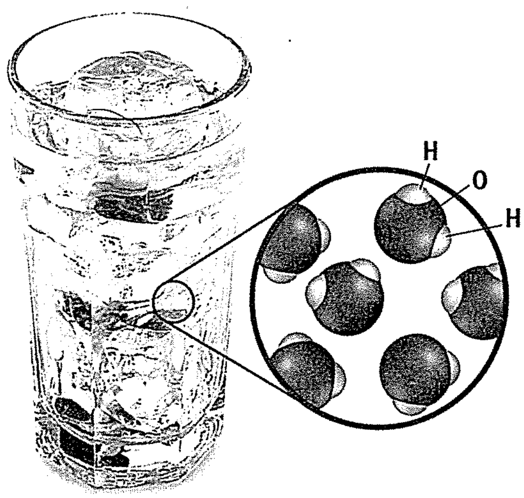


Figure 6 The water you drink is a compound consisting of hydrogen and oxygen atoms.
Identify *how hydrogen and oxygen are united to form water.*

Compounds When the atoms of more than one element combine, they form a compound. A **compound** contains atoms of more than one type of element that are chemically bonded together. Water, shown in **Figure 6,** is a compound in which two hydrogen atoms are bonded to each oxygen atom. Table salt—sodium chloride—is a compound consisting of sodium atoms bonded to chlorine atoms. Compounds are represented by chemical formulas that show the ratios and types of atoms in the compound. For example, the chemical formula for sodium chloride is NaCl. The formula for water is H_2O.

Reading Check *What atoms form the compound water?*

The properties of compounds often are very different from the properties of the elements that combine to form them. Sodium is a soft, silvery metal, and chlorine is a greenish, poisonous gas, but the compound they form is the white, crystalline table salt you use to season food. Under normal conditions on Earth, the hydrogen and oxygen that form water are gases. Water can be solid ice, liquid water, or gas. Which form do you think is most common for water at Earth's south pole?

Chemical Properties A property that describes a change that occurs when one substance reacts with another is called a chemical property. For example, one chemical property of water is that it changes to hydrogen gas and oxygen gas when an electric current passes through it. The chemical properties of a substance depend on what elements are in that substance and how they are arranged. Iron atoms in the mineral biotite will react with water and oxygen to form iron oxide, or rust, but iron mixed with chromium and nickel in stainless steel resists rusting.

Science Online

Topic: Periodic Table
Visit earth.msscience.com for Web links to information about the periodic table and chemical bonding.

Activity Research five elements that you are unfamiliar with and make a table showing their names, atomic number, properties, and how they are used.

Bonding

The forces that hold the atoms together in compounds are called chemical bonds. These bonds form when atoms share or exchange electrons. However, only those electrons having the highest energies in the electron cloud can form bonds. As you read in the last section, these are found farthest from the nucleus. An atom can have only eight electrons in this highest energy level. If more electrons exist, they must form a new, higher energy level. If an atom has exactly eight electrons in its outermost level, it is unlikely to form bonds. If an atom has fewer than eight electrons in its outermost level, it is unstable and is more likely to combine with other atoms.

Covalent Bonds Atoms can combine to form compounds in two different ways. One way is by sharing the electrons in their outermost energy levels. The type of bond that forms by sharing outer electrons is a covalent bond. A group of atoms connected by covalent bonds is called a **molecule.** For example, two atoms of hydrogen can share electrons with one atom of oxygen to form a molecule of water, as shown in **Figure 7.** Each of the hydrogen atoms has one electron in its outermost level, and the oxygen has six electrons in its outermost level. This arrangement causes hydrogen and oxygen atoms to bond together. Each of the hydrogen atoms becomes stable by sharing one electron with the oxygen atom, and the oxygen atom becomes stable by sharing two electrons with the two hydrogen atoms.

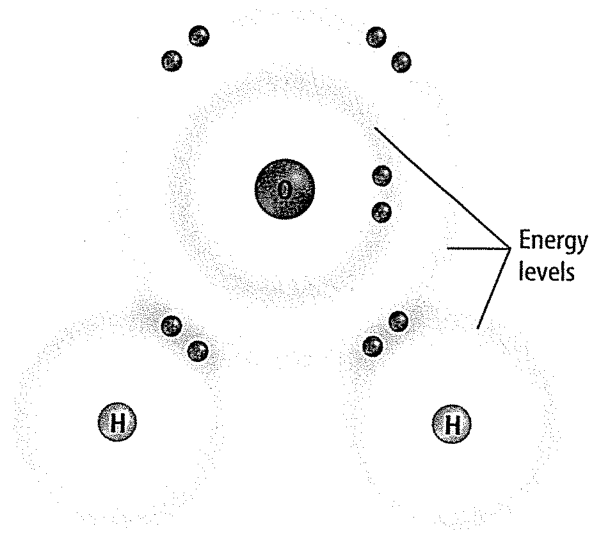


Figure 7 A molecule of water consists of two atoms of hydrogen that share outer electrons with one atom of oxygen.

Ionic Bonds In addition to sharing electrons, atoms also combine if they become positively or negatively charged. This type of bond is called an ionic bond. Atoms can be neutral, or under certain conditions, atoms can lose or gain electrons. When an atom loses electrons, it has more protons than electrons, so the atom is positively charged. When an atom gains electrons, it has more electrons than protons, so the atom is negatively charged. Electrically charged atoms are called **ions.**

Ions are attracted to each other when they have opposite charges. This is similar to the way magnets behave. If the ends of a pair of magnets have the same type of pole, they repel each other. Conversely, if the ends have opposite poles, they attract one another. Ions form electrically neutral compounds when they join. The mineral halite, commonly used as table salt, forms in this way. A sodium (Na) atom loses an outer electron and becomes a positively charged ion. As shown in **Figure 8,** if the sodium ion comes close to a negatively charged chlorine (Cl) ion, they attract each other and form the salt you use on french fries or popcorn.

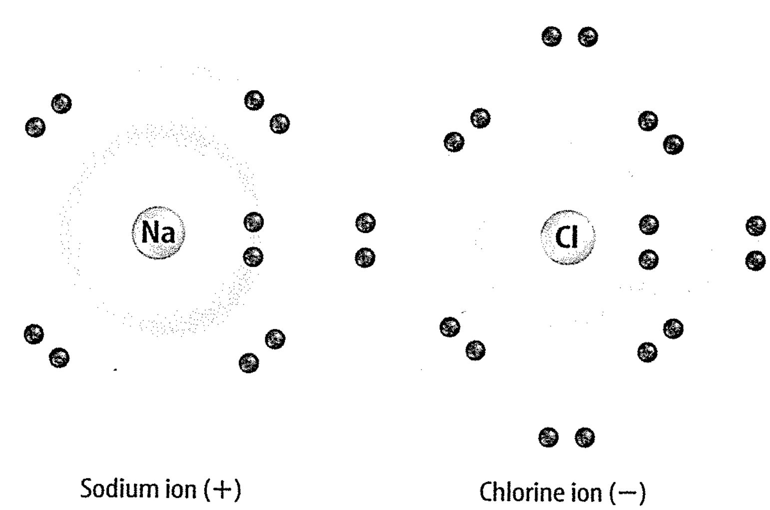


Figure 8 Table salt forms when a sodium ion and a chlorine ion are attracted to one another.
Draw Conclusions *What kind of bond holds ions together?*