chapter 6

Chemistry in Biology

section 1 Atoms, Elements, and Compounds

Before You Read

On the lines below, describe how you think chemistry relates to living things. Then read the section to learn about the chemical building blocks of matter.

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MAIN Idea

Matter is composed of tiny particles called atoms.

What You'll Learn

- the particles that make up atoms
- the difference between covalent bonds and ionic bonds
- about van der Waals forces

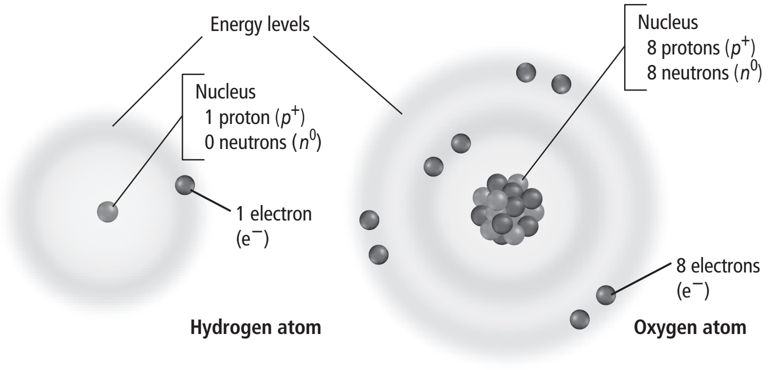
Read to Learn

Atoms

Chemistry is the study of matter. Matter is anything that has mass and takes up space. All organisms are made of matter. **Atoms** are the building blocks of matter.

Atoms are made up of neutrons, protons, and electrons, as shown in the figure below. The **nucleus** is the center of the atom where the neutrons and protons are located. **Protons** are positively charged particles (p^+). **Neutrons** are particles that have no charge (n^0). **Electrons** are negatively charged particles (e^-) that are located outside the nucleus.

Electrons move around the nucleus in energy levels. The atom's structure is the result of the attraction between protons and electrons. Atoms contain an equal number of protons and electrons. As a result, the overall charge of an atom is zero.



Mark the Text

Read for Understanding As you read this section, highlight any sentences that you do not understand. After you finish the section, reread the highlighted sentences.

Picture This

1. Identify the number of electrons in the outermost energy level of the oxygen atom.

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Elements

An **element** is a pure substance that cannot be broken down into other substances. The periodic table of elements organizes information about elements in rows, called periods, and columns, called groups. A periodic table is located inside the back cover of this workbook. Each block includes the element's name, number, symbol, and mass. Living things are composed mainly of three elements—carbon, hydrogen, and oxygen.

How are isotopes identified?

Atoms of the same element have the same number of protons and electrons but sometimes different numbers of neutrons. Atoms of the same element with different numbers of neutrons are called **isotopes**. Isotopes are identified by adding the number of protons and neutrons. Carbon-12 has six protons and six neutrons. Carbon-14 has six protons and eight neutrons.

Think it Over

2. Apply Another carbon isotope has six protons and seven neutrons in its nucleus. What do you think this carbon isotope is called?

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What makes an isotope radioactive?

Changing the number of neutrons in an atom can cause the nucleus to decay, or break apart. When a nucleus breaks apart, it gives off radiation. Isotopes that give off radiation are called radioactive isotopes. All living things contain the radioactive isotope carbon-14. Scientists know the half-life of carbon-14, or the amount of time it takes for half of carbon-14 to decay. By finding how much carbon-14 remains in an object, scientists can calculate the object's age.

Picture This

3. Draw Conclusions Table salt is a compound made of sodium and chlorine. Could you separate the sodium from the chlorine by crushing the salt crystals? Explain.

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Compounds

When two or more elements combine, they form a **compound**. Each compound has a chemical formula made up of the chemical symbols from the periodic table. For example, water is made of hydrogen (H) and oxygen (O). Its formula is H_2O. The table below lists characteristics of compounds.

Characteristics of Compounds	Example
Always formed from a specific combination of elements in a fixed ratio	Water is always a ratio of two hydrogen atoms and one oxygen atom: H_2O.
Chemically and physically different than the elements that comprise them	Water has different properties than hydrogen and oxygen.
Cannot be broken down into simpler compounds or elements by physical means	Passing water through a filter will not separate the hydrogen from the oxygen.
Can be broken down by chemical means	An electric current can break water down into hydrogen and oxygen.

Chemical Bonds

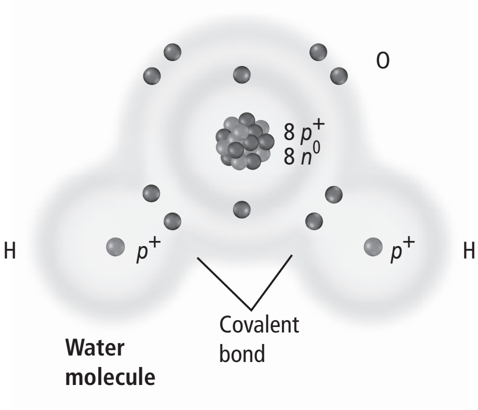
The force that holds substances together is called a chemical bond. Chemical bonding involves electrons. Electrons travel around the nucleus of an atom in energy levels. Each energy level can hold only a certain number of electrons. The first energy level, which is closest to the nucleus, can hold up to two electrons. The second level can hold up to eight electrons.

A partially-filled energy level is not as stable as a full or an empty energy level. Atoms become more stable by losing electrons or attracting electrons from other atoms. This electron activity forms chemical bonds between atoms. The forming of chemical bonds stores energy. The breaking of chemical bonds releases energy for an organism's life processes—growth, development, and reproduction. The two main types of chemical bonds are covalent and ionic.

How do covalent bonds form?

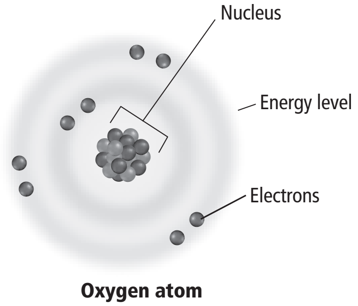
A **covalent bond** forms when atoms share electrons. The figure below shows the covalent bonds between oxygen and hydrogen to form water. Each hydrogen (H) atom has one electron in its outer energy level, and the oxygen (O) atom has six. The outer energy level of oxygen is the second level, so it can hold up to eight electrons. Oxygen has a strong tendency to fill the energy level by sharing electrons from the two nearby hydrogen atoms. Hydrogen also has a strong tendency to share electrons with oxygen to fill its outer energy level. Two covalent bonds form a water molecule.

Most compounds in living things are molecules. A **molecule** is a compound in which the atoms are held together by covalent bonds. Covalent bonds can be single, double, or triple. A single bond shares one pair of electrons. A double bond shares two pairs of electrons. A triple bond shares three pairs of electrons.



Think it Over

4. Apply Study the oxygen atom illustrated below. Is the second energy level of the oxygen atom full? Explain.



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Picture This

5. Label the first energy level and second energy level in the oxygen atom. Include in each label the number of electrons required to fill the level.

How do ionic bonds form?

Recall that atoms do not have an electric charge. Also recall that an atom is most stable when its outer energy level is either empty or full. To become more stable, an atom might give up electrons to empty its outer energy level. Or, the atom might accept electrons to fill the outer energy level. An atom that has given up or gained one or more electrons becomes an **ion** and carries an electric charge.

For example, the outer energy level of sodium (Na) has one electron. Sodium can become more stable if it gives up this electron to empty the energy level. When it gives up this electron, the neutral sodium atom becomes a positively charged sodium ion (Na^+). Chlorine (Cl) needs just one electron to fill its outer energy level. When it accepts an electron from another atom, chlorine becomes a negatively charged ion (Cl^-).

Reading Check

6. **Describe** what happens to an atom's electric charge if the atom gives up an electron.

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An **ionic bond** is an electrical attraction between two oppositely charged ions. When sodium gives its electron to chlorine, the positively charged sodium ion (Na^+) is attracted to the negatively charged chlorine ion (Cl^-). The ionic bond between them forms the ionic compound sodium chloride (NaCl), or table salt.

Ions in living things help maintain homeostasis as they travel in and out of cells. Ions also help transmit signals that enable you to see, taste, hear, feel, and smell.

Some atoms give up or accept electrons more easily than other atoms. The elements identified as metals in the periodic table tend to give up electrons. The elements identified as nonmetals tend to accept electrons.

van der Waals Forces

Electrons travel around the nucleus randomly. The random movement can cause an unequal distribution of electrons around the molecule. This creates temporary areas of slightly positive and negative charges. Attractions between these positive and negative regions hold molecules together. These attractions between molecules are called **van der Waals forces**. These forces are not as strong as covalent and ionic bonds, but they play a key role in biological processes. For example, attractions between positive and negative regions hold water molecules together. As a result, water can form droplets. Note that van der Waals forces are the attractive forces between water molecules. They are not the forces between the atoms that make up water.

Reading Check

7. **Identify** the substances that are held together by van der Waals forces. (Circle your answer.)
   a. atoms
   b. molecules