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# I. MOLECULAR BASIS OF LIFE

All living and nonliving things are composed of **matter**; that is, they occupy space and have mass. Matter can exist in three phases—solid, liquid, or gas—and is composed of building blocks, the chemical **elements**. At present 109 different elements have been identified. Ninety-two of these occur in nature; the remainder are man-made. Only 25 elements are found in living organisms. Elements are symbolized by the abbreviations of their English or Latin names. The abundance of each element varies.

In the late eighteenth century, a French scientist named Antoine Lavoisier, the “Father of Modern Chemistry,” showed that organisms are composed of the same chemical elements as nonliving things. He demonstrated that carbon, hydrogen, oxygen, and nitrogen are the principal elements of living things. We have since learned that organisms contain substantial amounts of sulfur, phosphorus, calcium, potassium, iron, sodium, magnesium, and chlorine. Trace amounts of additional elements have also been found.

**TABLE 1: ESSENTIAL ELEMENTS IN LIVING ORGANISMS**

	ELEMENT	SYMBOL	ATOMIC NUMBER	FUNCTION
<b>Most Abundant</b>	Hydrogen	H	1	water and organic compounds
	Carbon	C	6	all organic compounds
	Nitrogen	N	7	all amino acids
	Oxygen	O	8	water; cell respiration; organic compounds
<b>Less Abundant</b>	Sodium	Na	11	membrane polarization
	Magnesium	Mg	12	chlorophyll; cofactor
	Phosphorus	P	15	energy transfer; many organic compounds
	Sulfur	S	16	some amino acids; some organic compounds
	Chlorine	Cl	17	membrane polarization
	Potassium	K	19	membrane polarization
	Calcium	Ca	20	bones and teeth; muscle contraction and cofactor
	Iron	Fe	26	hemoglobin; cofactor
<b>Trace Amounts</b>	Boron	B	5	plant metabolism
	Fluorine	F	9	teeth and bone growth
	Silicon	Si	14	growth; diatom structure
	Vanadium	V	23	growth factor
	Chromium	Cr	24	insulin function
	Manganese	Mn	25	cofactor
	Cobalt	Co	27	Vitamin B <sub>12</sub> structure; cofactor
	Copper	Cu	29	hemocyanin; oxidative enzymes
	Zinc	Zn	30	cofactor
	Selenium	Se	34	liver function
	Molybdenum	Mo	42	cofactor
	Tin	Sn	50	role? but essential
	Iodine	I	53	thyroid hormone

## SECTION OBJECTIVES

**Read these objectives.** When you have completed this section, you should be able:

1. To diagram an atom.
2. To identify and to write the names and symbols of principal chemical elements found in living organisms.
3. To define and to describe a molecule.

## VOCABULARY



**Study these words** to enhance your learning success in this section.

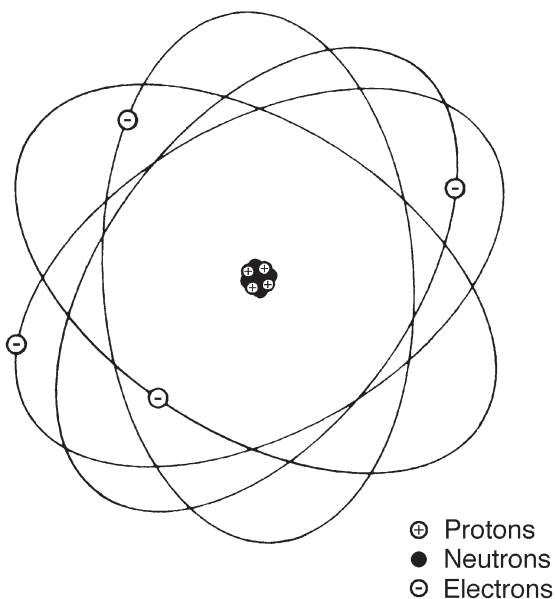
atom	electron	neutron
atomic number	element	nucleus
atomic mass	matter	orbital
compound	mixture	proton
diatomic	molecule	

**NOTE:** All vocabulary words in this LightUnit appear in **boldface** print the first time they are used. If you are unsure of the meaning when you are reading, refer to the definitions given in the glossary at the back of the book.

## STRUCTURE OF ELEMENTS

Elements are made up of building blocks called **atoms**. Each element contains only one type of atom. For example, a tank of helium gas contains only helium atoms; a piece of pure gold contains only gold atoms. Atoms are extremely small. If 50 million of the largest atoms were placed side by side, the estimated measure would be one inch.

Atoms are composed of smaller structural units. An inner **nucleus** makes up most of the mass of the atom. It is composed of two primary particles: **protons** ( $p^+$ ), *positively* charged particles which give the nucleus a positive charge; and **neutrons** ( $n$ ), which are neutral particles. Protons are responsible for giving the element its chemical properties. Outside the centralized nucleus are small *negatively* charged particles called **electrons** ( $e^-$ ). These electrons revolve around the nucleus in **orbitals**. The number of electrons in an atom equals the number of protons, balancing the charge and making the atom electrically neutral. The electrons are those parts of an atom



**Figure 1: Model of Atomic Structure**

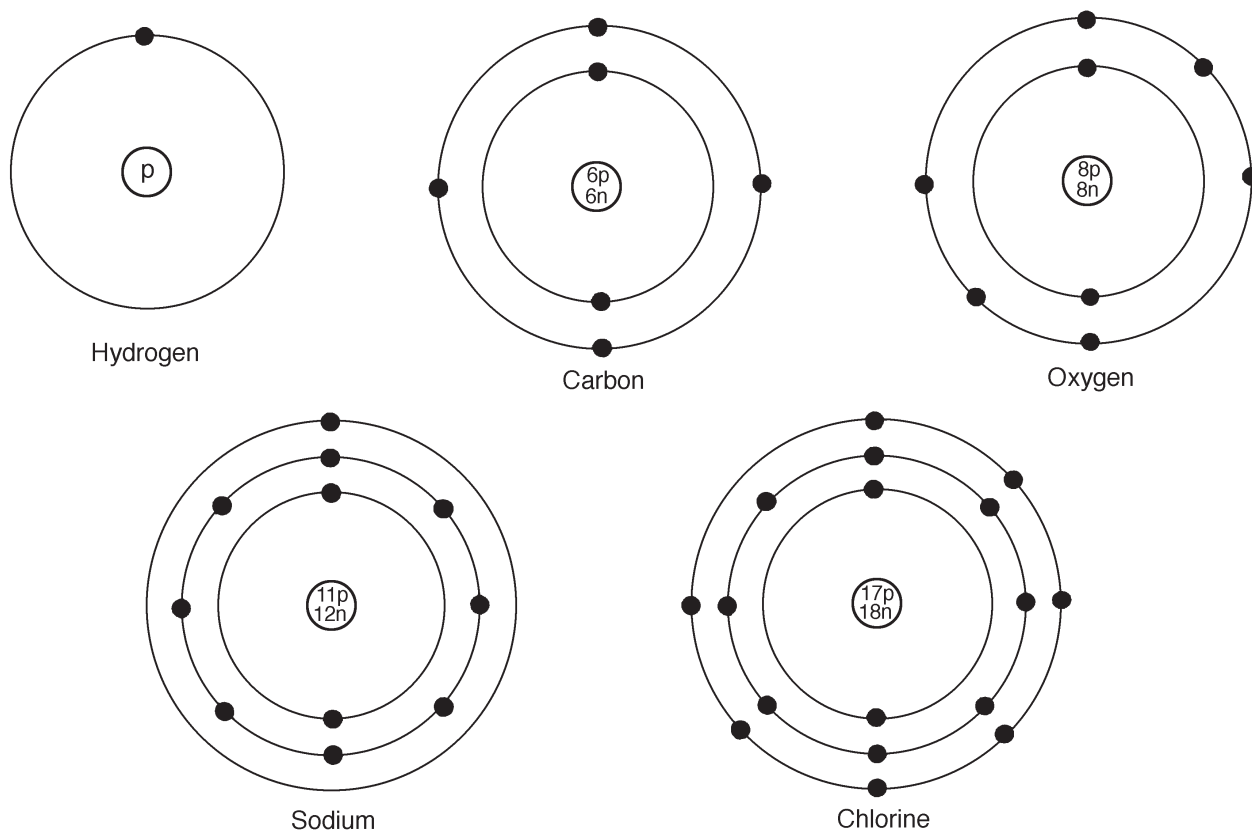
that participate in chemical reactions. The distribution of the electrons determines the kind of chemical reactions in which elements will participate.

The model of atomic structure (Figure 1) illustrates the distribution of subatomic particles. The nucleus of hydrogen contains one proton; helium, two protons; carbon, six protons; nitrogen, seven; oxygen, eight; and so on. The number of protons in the nucleus is called the **atomic number** and is specific to that element.

The fact that the majority of the mass in an atom is found in the nucleus results from the relatively large mass of protons and neutrons and the extremely small mass of electrons. The number of protons and neutrons in the nucleus is referred to as the **atomic mass**

of the atom. (Sometimes this number is referred to inaccurately as the atomic *weight*.) In a neutral atom, electrons are present in the same number as protons, but the mass of an electron is much smaller than the mass of a proton.

Electrons are neither fixed in a stationary position nor wander at random, but they move in predictable manners. The orbitals in which the electrons travel are separated in space to reduce the repulsive force between electrons, but they are close enough to the nucleus to be within the attractive force of the protons.



**Figure 2: Examples of Atomic Structures**

Notice from Figure 2 that electrons have a definite distribution. The orbital nearest the nucleus never contains more than two elec-

trons. The second orbital contains a maximum of eight electrons. Section II will deal with electron distribution in detail.



**Complete these statements.**

- 1.1 Atoms are composed of (a) \_\_\_\_\_, (b) \_\_\_\_\_, and (c) \_\_\_\_\_.
- 1.2 Of the three atomic particles in 1.1, the smallest are the \_\_\_\_\_.
- 1.3 Atomic mass is determined by the (a) \_\_\_\_\_ plus (b) \_\_\_\_\_.
- 1.4 Atomic number is the number of an atom's \_\_\_\_\_.



Complete the chart using information from Figure 2.

	Symbol	Number of Protons	Number of Neutrons	Number of Electrons	Atomic Number	Atomic Mass
1.5 Hydrogen	H	a. _____	b. _____	c. _____	d. _____	e. _____
1.6 Carbon	C	a. _____	b. _____	c. _____	d. _____	e. _____
1.7 Oxygen	O	a. _____	b. _____	c. _____	d. _____	e. _____
1.8 Sodium	Na	a. _____	b. _____	c. _____	d. _____	e. _____
1.9 Chlorine	Cl	a. _____	b. _____	c. _____	d. _____	e. _____



Diagram an atom of each given element and label the parts.

1.10 Sodium (atomic number = 11; atomic mass = 23)

1.11 Fluorine (atomic number = 9; atomic mass = 19)

## MOLECULES AND COMPOUNDS

Few elements exist as free atoms in nature. Most atoms are combined with others to form larger units called **molecules**. For example, the air we breathe contains oxygen in molecular form, which is the result of two oxygen atoms combining.

Two or more atoms of different elements may combine to form a molecule of a substance entirely different from the atoms that make it up. New substances so formed are called **compounds**. For example, two atoms of hydrogen ( $H_2$ ) joined with one atom of oxygen (O) form the compound water ( $H_2O$ ).

Pure compounds are rarely found in nature; generally a **mixture** of several compounds is present. The air we breathe is a mixture of molecular nitrogen ( $N_2$ ), oxygen ( $O_2$ ), water ( $H_2O$ ), and other less abundant gases.

When more than one atom is present in a molecule, the number of atoms is represented by a subscript. The molecule of water ( $H_2O$ ) has two atoms of hydrogen and one atom of oxygen.  $H_2$  and  $N_2$  represent **diatomic** molecules of hydrogen and nitrogen, respectively.