1–1 ATOMIC STRUCTURE

All matter is made of atoms; and all atoms consist of electrons, protons, and neutrons. In this section, you will learn about the structure of the atom, electron orbits and shells, valence electrons, ions, and two semiconductive materials—silicon and germanium. Semiconductive material is important because the configuration of certain electrons in an atom is the key factor in determining how a given material conducts electrical current.

After completing this section, you should be able to

- **Discuss the basic structure of atoms**
- Define *nucleus, proton, neutron*, and *electron*
- Describe an element's atomic number
- Explain electron shells
- Describe a valence electron
- Describe ionization
- Describe a free electron

An **atom*** is the smallest particle of an element that retains the characteristics of that element. Each of the known 109 elements has atoms that are different from the atoms of all other elements. This gives each element a unique atomic structure. According to the classical Bohr model, atoms have a planetary type of structure that consists of a central nucleus surrounded by orbiting electrons, as illustrated in Figure 1–1. The **nucleus** consists of positively charged particles called **protons** and uncharged particles called **neutrons**. The basic particles of negative charge are called **electrons**.

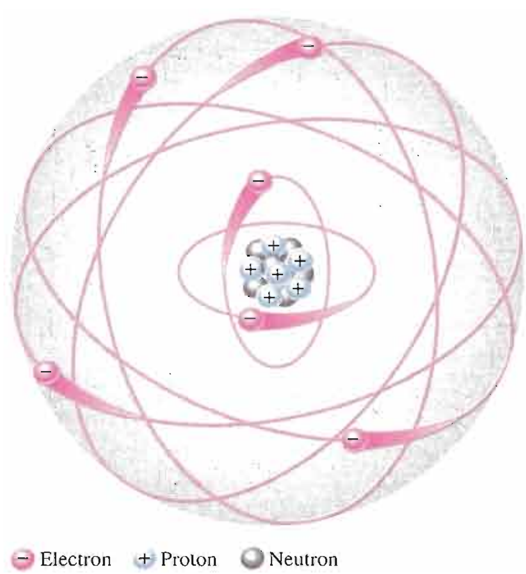
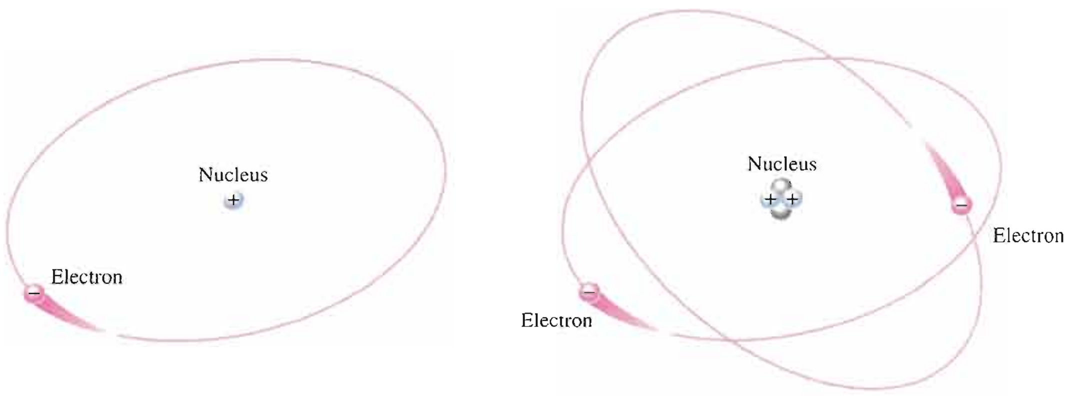


FIGURE 1–1

The Bohr model of an atom showing electrons in orbits around the nucleus, which consists of protons and neutrons. The "tails" on the electrons indicate motion.

*All bold terms are in the end-of-book glossary. The bold terms in color are key terms and are also defined at the end of the chapter.

Each type of atom has a certain number of electrons and protons that distinguishes it from the atoms of all other elements. For example, the simplest atom is that of hydrogen, which has one proton and one electron, as shown in Figure 1–2(a). As another example, the helium atom, shown in Figure 1–2(b), has two protons and two neutrons in the nucleus and two electrons orbiting the nucleus.



(a) Hydrogen atom (b) Helium atom

▲ **FIGURE 1–2**

Two simple atoms, hydrogen and helium.

Atomic Number

All elements are arranged in the periodic table of the elements in order according to their atomic number. The **atomic number** equals the number of protons in the nucleus, which is the same as the number of electrons in an electrically balanced (neutral) atom. For example, hydrogen has an atomic number of 1 and helium has an atomic number of 2. In their normal (or neutral) state, all atoms of a given element have the same number of electrons as protons; the positive charges cancel the negative charges, and the atom has a net charge of zero.

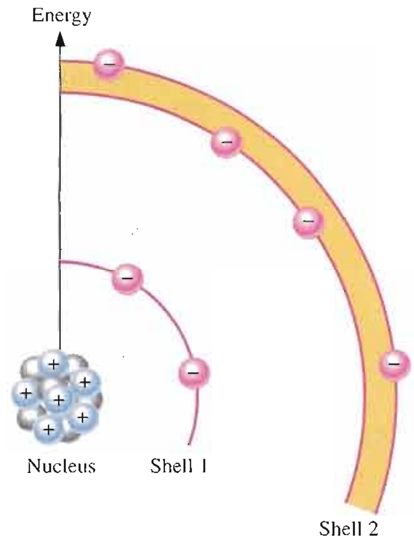
Electron Shells and Orbits

Electrons orbit the nucleus of an atom at certain distances from the nucleus. Electrons near the nucleus have less energy than those in more distant orbits. It is known that only discrete (separate and distinct) values of electron energies exist within atomic structures. Therefore, electrons must orbit only at discrete distances from the nucleus.

Energy Levels Each discrete distance (**orbit**) from the nucleus corresponds to a certain energy level. In an atom, the orbits are grouped into energy bands known as **shells**. A given atom has a fixed number of shells. Each shell has a fixed maximum number of electrons at permissible energy levels (orbits). The differences in energy levels within a shell are much smaller than the difference in energy between shells. The shells are designated 1, 2, 3, and so on, with 1 being closest to the nucleus. Some references designate shells by the letters *K, L, M*, and so on. This energy band concept is illustrated in Figure 1–3, which shows the 1st shell with one energy level and the 2nd shell with two energy levels. Additional shells may exist in other types of atoms, depending on the element.

FIGURE 1–3

Energy increases as the distance from the nucleus increases.



Valence Electrons

Electrons that are in orbits farther from the nucleus have higher energy and are less tightly bound to the atom than those closer to the nucleus. This is because the force of attraction between the positively charged nucleus and the negatively charged electron decreases with increasing distance from the nucleus. Electrons with the highest energy exist in the outermost shell of an atom and are relatively loosely bound to the atom. This outermost shell is known as the **valence** shell and electrons in this shell are called *valence electrons*. These valence electrons contribute to chemical reactions and bonding within the structure of a material and determine its electrical properties.

Ionization

When an atom absorbs energy from a heat source or from light, for example, the energies of the electrons are raised. The valence electrons possess more energy and are more loosely bound to the atom than inner electrons, so they can easily jump to higher orbits within the valence shell when external energy is absorbed.

If a valence electron acquires a sufficient amount of energy, it can actually escape from the outer shell and the atom's influence. The departure of a valence electron leaves a previously neutral atom with an excess of positive charge (more protons than electrons). The process of losing a valence electron is known as **ionization**, and the resulting positively charged atom is called a *positive ion*. For example, the chemical symbol for hydrogen is H. When a neutral hydrogen atom loses its valence electron and becomes a positive ion, it is designated H^+. The escaped valence electron is called a **free electron**. When a free electron loses energy and falls into the outer shell of a neutral hydrogen atom, the atom becomes negatively charged (more electrons than protons) and is called a *negative ion*, designated H^-.

The Number of Electrons in Each Shell

The maximum number of electrons (N_e) that can exist in each shell of an atom is a fact of nature and can be calculated by the formula,

Equation 1–1
$$N_e = 2n^2$$

where n is the number of the shell. The innermost shell is number 1, the next shell is number 2, and so on. The maximum number of electrons that can exist in the innermost shell (shell 1) is

$$N_e = 2n^2 = 2(1)^2 = 2$$