Pearson

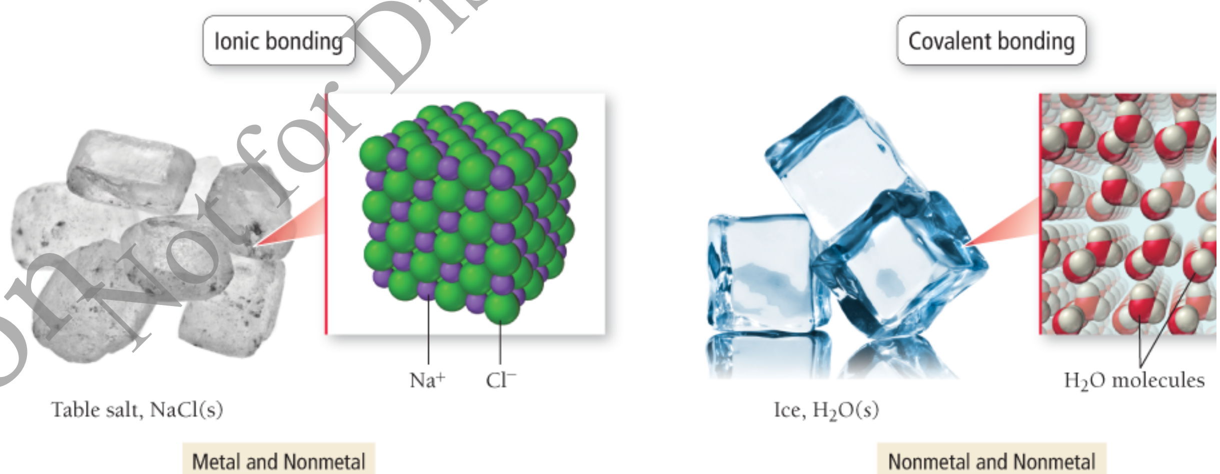
4.2: Types of Chemical Bonds

A **chemical bond** is the force that holds atoms together in a compound. We begin our discussion of chemical bonding by asking why bonds form in the first place. The answer to this question is not simple and involves not only quantum mechanics but also some thermodynamics that we do not cover until Chapter 18. Nonetheless, we can address an important *aspect* of the answer now: *Chemical bonds form because they lower the potential energy of the charged particles that compose atoms.*

Recall from Section 3.5 that when an outer principal quantum level is completely full, the overall potential energy of the electrons that occupy that level is particularly low. Recall also that only the noble gases have full outer principal quantum levels. Because the rest of the elements do *not* possess the stability of the noble gases, they form chemical bonds to become more stable (to lower the potential energy of the charged particles that compose them).

As we have already seen, atoms are composed of particles with positive charges (the protons in the nucleus) and negative charges (the electrons). When two atoms approach each other, the electrons of one atom are attracted to the nucleus of the other according to Coulomb's law (see Section 3.3) and vice versa. However, at the same time, the electrons of each atom repel the electrons of the other, and the nucleus of each atom repels the nucleus of the other. The result is a complex set of interactions among a large number of charged particles. If these interactions lead to an overall net reduction of potential energy between the charged particles, a chemical bond forms. Bonding theories help us to predict the circumstances under which bonds form and also the properties of the resultant molecules. We broadly classify chemical bonds into two types—*ionic* and *covalent*—depending on the kind of atoms involved in the bonding (Figure 4.2).

Figure 4.2 Ionic and Covalent Bonding

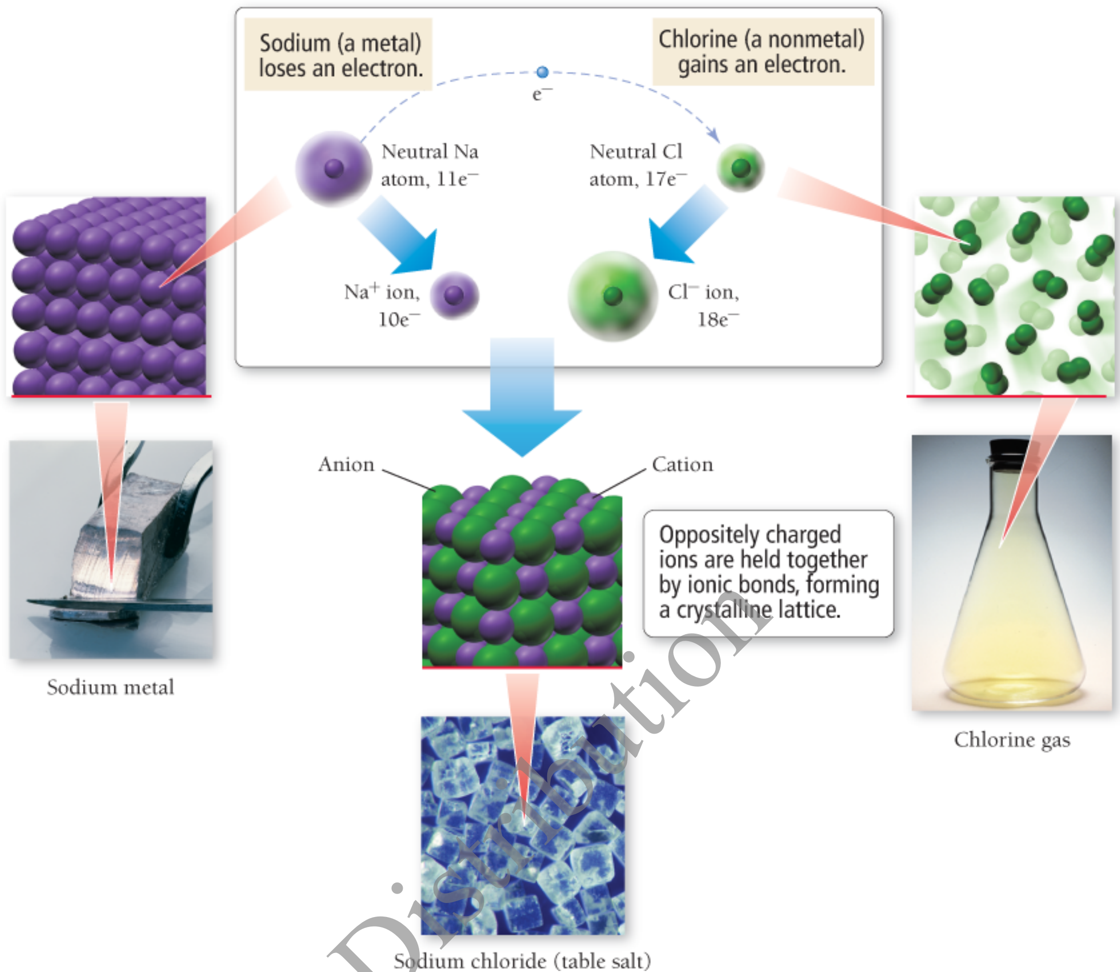


The bond that forms between a metal and a nonmetal is an **ionic bond**. Recall from Chapter 3 that metals have a tendency to lose electrons and that nonmetals have a tendency to gain them. Therefore, when a metal interacts with a nonmetal, it can transfer one or more of its electrons to the nonmetal. The metal atom then becomes a *cation* (a positively charged ion), and the nonmetal atom becomes an *anion* (a negatively charged ion), as shown in Figure 4.3. These oppositely charged ions attract one another according to Coulomb's law and form an **ionic compound**, which in the solid state is composed of a *lattice*—a regular three-dimensional array—of alternating cations and anions.

Figure 4.3 The Formation of an Ionic Compound

An atom of sodium (a metal) loses an electron to an atom of chlorine (a nonmetal), creating a pair of oppositely charged ions. The sodium cation then attracts the chloride anion, and the two form a crystalline lattice.

The Formation of an Ionic Compound



The bond that forms between two or more nonmetals is a **covalent bond**. In Chapter 3 we saw that nonmetals tend to have high ionization energies (their electrons are relatively difficult to remove). Therefore, when a nonmetal bonds with another nonmetal, neither atom transfers electrons to the other. Instead, the two atoms *share* some electrons. The shared electrons interact with the nuclei of both of the bonding atoms, lowering their potential energy in accordance with Coulomb's law. Covalently bonded atoms form *molecules*, and the resulting compounds are called **molecular compounds**.

We can understand the stability of a covalent bond by considering the most stable arrangement (the one with the lowest potential energy) of two positively charged particles separated by a small distance and a negatively charged particle. As Figure 4.4 illustrates, the arrangement in which the negatively charged particle lies *between* the two positively charged ones has the lowest potential energy because in this arrangement, the negatively charged particle interacts most strongly with *both of the positively charged ones*. In a sense, the negatively charged particle holds the two positively charged ones together. Similarly, shared electrons in a covalent chemical bond *hold* the bonding atoms together by attracting the positive charges of their nuclei.

Figure 4.4 Possible Configurations of One Negatively Charged Particle and Two Positively Charged Ones