

5.1 Ionic and covalent bonding

We begin by applying simple bonding theories to molecular chlorine gas (Cl_2) and non-molecular sodium chloride (NaCl), whose structures were discussed in Section 2. Figure 5.3 shows the result.

Figure 5.3a shows the **Lewis structure** of the Cl_2 molecule. Note that the electrons are grouped in pairs. This reflects the pairing of electrons in atomic orbitals noted in Section 4.4. The ions in sodium chloride have also been represented in this way in Figure 5.3b. The chloride ion has the shell structure of argon, with eight outer electrons, and the electron transferred from the sodium atom is marked by a small filled circle. In both structures, the formation of a chemical bond involves the production of a new electron pair in the outer shell of chlorine. However, in Cl_2 , because the two atoms are identical, the electron pair must be equally shared between the two atoms; in NaCl by contrast, it resides on the resulting chloride ion.

From this contrast flows the difference in properties between the two substances. The transference of the electron to chlorine in NaCl produces ions, each of which can exist independently of any one partner. So in sodium chloride, each ion is surrounded by as many ions of opposite charge as space allows. In this case the number is six, as you saw in Figure 2.10. Figure 5.4 is Figure 2.10 adjusted to show the presence of ions. Because of the strong attractive forces existing between the closely packed ions of opposite charge, the sodium chloride structure is not easily broken down: it has a high melting temperature and does not dissolve in organic solvents like the liquid hydrocarbons found in petrol, or dry-cleaning fluid. When it does melt, or dissolve in water, the ions separate and the resulting ionic fluid conducts electricity. Compounds of this type are called *ionic*, and the type of bonding is called *ionic bonding*.

By contrast, in Cl_2 , the electron pair is shared. This is called *covalent bonding*. Here, the bonding can be maintained only if the atoms stay together in pairs, so it gives rise to a molecular substance: elemental chlorine consists of discrete Cl_2 molecules with only weak forces acting between them. It is a gas at room temperature, and dissolves easily in liquid hydrocarbons, including petrol. However, because a solution of chlorine contains no ions, it does not conduct electricity.

- According to this picture, ionic and covalent bonding are the same process carried to different extents; what is the process, and how do the extents differ?
- The common process is the formation of an electron-pair bond; in covalent bonding the electron pair is shared between the atoms involved; in ionic bonding it resides on just one of them.

This link between ionic and covalent bonding is clarified by the concept of *electronegativity*. The electronegativity of an element is a measure of the power of its atom to attract electrons to itself *when forming chemical bonds*. In the Cl_2 molecule, the two identical atoms have an equal appetite for electrons: their electronegativities are equal, so the electron pair is shared equally between them. Now consider sodium chloride.

- Which atom is the more electronegative, sodium or chlorine?

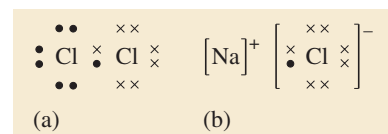


Figure 5.3 Lewis structures for (a) gaseous Cl_2 and (b) solid NaCl . Chlorine has seven outer electrons, but can acquire an additional electron to give eight, and the shell structure of argon, if an electron pair is shared between the two atoms in Cl_2 . Sodium has one outer electron, so sodium can acquire a neon shell, and chlorine an argon shell structure if this electron is transferred to a chlorine atom. This generates the Na^+ and Cl^- ions in sodium chloride.

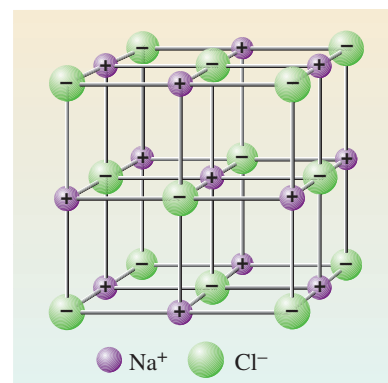


Figure 5.4 An ionic picture of solid sodium chloride which explains important properties of the substance. The solid is regarded as an assembly of Na^+ and Cl^- ions.