# CHAPTER 4 CHEMICAL BONDING

## Reflect on Your Learning

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1. *[likely initial answer]* When elements react, the product will be a molecular compound if the reactants are both nonmetals, like chlorine and phosphorus; and the product will be an ionic compound if the reactants are a nonmetal and a metal, like chlorine and potassium.
   *[a more complete answer]* When two nonmetals such as chlorine and phosphorus react, the relatively small difference in electronegativities results in a sharing of valence electrons to produce a covalently bonded molecule. Molecular substances may be solids, liquids, or gases, depending on the intermolecular forces present, and are nonconductors of electricity in any state, including aqueous. When a nonmetal and a metal such as chlorine and potassium react, the relatively large difference in electronegativities results in a transfer of one or more valence electrons from the metal to the nonmetal, producing positive and negative ions. Ionic substances are always solids at ambient temperatures, generally hard with high melting points, and conduct electricity in their molten and aqueous states.
2. *[likely initial answer]* We can explain and predict the bonding of some small, simple molecules with Lewis diagrams, using the octet rule.
   *[a more complete answer]* We can explain and predict the bonding of some small, simple molecules by considering the valence orbitals in an electron configuration. A half-filled valence orbital on one atom can overlap with another half-filled valence orbital on a second atom to form a combined orbital with a pair of electrons of opposite spin. Considering either the shape of these valence orbitals or simply the number of groups of bonded electrons around a central atom, we can explain or predict the shape of a small molecule.
3. *[likely initial answer]* A structural diagram can be drawn for the molecular compounds: $C_5H_{12(l)}$, $CH_3OH_{(l)}$, and $CO_{2(s)}$. These substances will all be nonconductors of electricity in any state. Sodium, $Na_{(s)}$, is made up of sodium atoms and is a shiny, silvery solid that conducts electricity very well. Sodium chloride, $NaCl_{(s)}$, is an ionic compound made up of sodium and chloride ions. Sodium chloride is soluble in water and the solution conducts electricity. Diamond, $C_{(s)}$, is made up of carbon atoms and is a clear, colourless, very hard solid.
   *[a more complete answer]*
   $C_5H_{12(l)}$ is a molecular compound whose molecules contain five carbon atoms each with a tetrahedral arrangement of four single covalent bonds. This substance is nonpolar with a low melting and boiling point due to weak intermolecular attractive forces; and is probably not soluble in water.
   $CH_3OH_{(l)}$ is a molecular compound whose molecules contain a carbon atom with a tetrahedral arrangement of four single covalent bonds and an oxygen atom with a V-shaped arrangement of two single covalent bonds. This polar compound has a somewhat higher melting and boiling point, compared to similar-sized nonpolar molecules, due to hydrogen bonding intermolecular attractive forces; and is probably soluble in water.
   $Na_{(s)}$ is a metallic element with sodium cations in a sea of mobile valence electrons which produces a non-directional bonding. This explains its mechanical properties and electrical conductivity. The low electronegativity of a sodium atom partly explains its reactivity and tendency to form ionic compounds.
   $NaCl_{(s)}$ is an ionic compound, with strong ionic bonding between its cations and anions. The ions are arranged in a lattice structure with a regular repeating pattern of alternating positive and negative ions. The structure explains its crystalline nature, hardness, and relatively high melting and boiling point.
   $CO_{2(s)}$ is a molecular compound with linear molecules containing double covalent bonds between the carbon and the oxygen atoms. The bond dipoles cancel to produce a nonpolar molecule. Because the molecules are relatively small and only London forces exist between them, the melting and boiling point should be relatively low.
   $C_{(s)}$ (diamond) is a nonmetallic element with a continuous network of carbon atoms connected to each other in a tetrahedral bonding arrangement. A diamond is like a single macromolecule. The 3-D arrangement of relatively strong covalent bonds explains its great hardness and very high melting and boiling point.

## Try This Activity: Properties and Forces

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(a) The glass and the plate do not slide over each other easily when pressed together.
(b) Dishwashing liquid does not make the surface between the glass and plate slippery when they are pressed together.
(c) The gear oil does make the contact surface between the glass and plate slippery, even when they are pressed together.
(d) Dishwashing liquid seems to be a more effective adhesive.

(e) Dishwashing liquid molecules must attract water molecules better than they attract each other because water dissolves the substance and washes it away. Gear oil molecules must attract each other better than they attract water molecules—because water doesn't dissolve the oil or wash it away.
(f) We observe that the dishwashing liquid will mix with (dissolve) the oil, and the mixture (solution) of the two will dissolve in water, and be washed away. It seems that dishwashing liquid molecules are somehow able to attract both water molecules and oil molecules.
(g) Dishwasher detergent is thick and viscous, so its molecules are quite cohesive, and seem to be adhesive to glass and water and oil. Gear oil molecules are less cohesive, and not very adhesive to glass or water—only to the dishwashing liquid. This seems logical, since dishwashing liquids are designed to attract and dissolve all kinds of food materials; and gear oil is designed to make metal surfaces slide against each other without wearing down.

## 4.1 LEWIS THEORY OF BONDING

### PRACTICE

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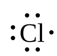
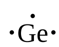
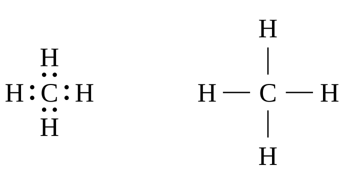
### Understanding Concepts

1. (a) Mg - 2, Cl - 1
   (b) C - 4, H - 1
   (c) H -1, O - 2
   (d) H - 2, S - 2
   (e) N - 3, H - 1
2. In the order that they were created by chemists, we have the (c) Dalton atom, (b) empirical formulas, (d) Kekulé structures, (a) Lewis structures, and (e) Schrödinger quantum mechanics.
3. (a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ 
   (b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ 
   (c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ 
   (d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$ 
4. (a) 
   (b) 
   (c) 
   (d) Rb·
5. (a) 
   (b)