

# Molecular Geometry

## SECTION 5

### OBJECTIVES

- Explain VSEPR theory.
- Predict the shapes of molecules or polyatomic ions using VSEPR theory.
- Explain how the shapes of molecules are accounted for by hybridization theory.
- Describe dipole-dipole forces, hydrogen bonding, induced dipoles, and London dispersion forces and their effects on properties such as boiling and melting points.
- Explain what determines molecular polarity.

The properties of molecules depend not only on the bonding of atoms but also on molecular geometry—the three-dimensional arrangement of a molecule’s atoms in space. The polarity of each bond, along with the geometry of the molecule, determines *molecular polarity*, or the uneven distribution of molecular charge. As you will read, molecular polarity strongly influences the forces that act *between* molecules in liquids and solids.

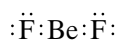
A chemical formula reveals little information about a molecule’s geometry. After performing many tests designed to reveal the shapes of various molecules, chemists developed two different, equally successful theories to explain certain aspects of their findings. One theory accounts for molecular bond angles. The other is used to describe the orbitals that contain the valence electrons of a molecule’s atoms.

### VSEPR Theory

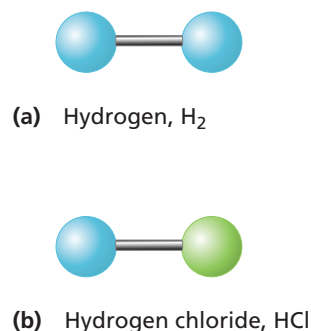
As shown in **Figure 20**, diatomic molecules, like those of hydrogen,  $\text{H}_2$ , and hydrogen chloride,  $\text{HCl}$ , must be linear because they consist of only two atoms. To predict the geometries of more-complicated molecules, one must consider the locations of all electron pairs surrounding the bonded atoms. This is the basis of VSEPR theory.

The abbreviation VSEPR stands for “valence-shell, electron-pair repulsion,” referring to the repulsion between pairs of valence electrons of the atoms in a molecule. **VSEPR theory states that repulsion between the sets of valence-level electrons surrounding an atom causes these sets to be oriented as far apart as possible.** How does the assumption that electrons in molecules repel each other account for molecular shapes? For now let us consider only molecules with no unshared valence electron pairs on the central atom.

Let’s examine the simple molecule  $\text{BeF}_2$ . The beryllium atom forms a covalent bond with each fluorine atom and does not follow the octet rule. It is surrounded by only the two electron pairs that it shares with the fluorine atoms.



According to VSEPR theory, the shared pairs will be as far away from each other as possible. As shown in **Figure 21a** on the next page, the distance between electron pairs is maximized if the bonds to fluorine are



**FIGURE 20** Ball-and-stick models illustrate the linearity of diatomic molecules. (a) A hydrogen molecule is represented by two identical balls (the hydrogen atoms) joined by a solid bar (the covalent bond). (b) A hydrogen chloride molecule is composed of dissimilar atoms, but it is still linear.