# Chapter 11: Intermolecular Forces

(Sections 1–9 only)

**Chemical Forces**

**Bonding:**

- Ionic
- Covalent

**Nonbonding:**

- Intermolecular forces

# Intermolecular Forces

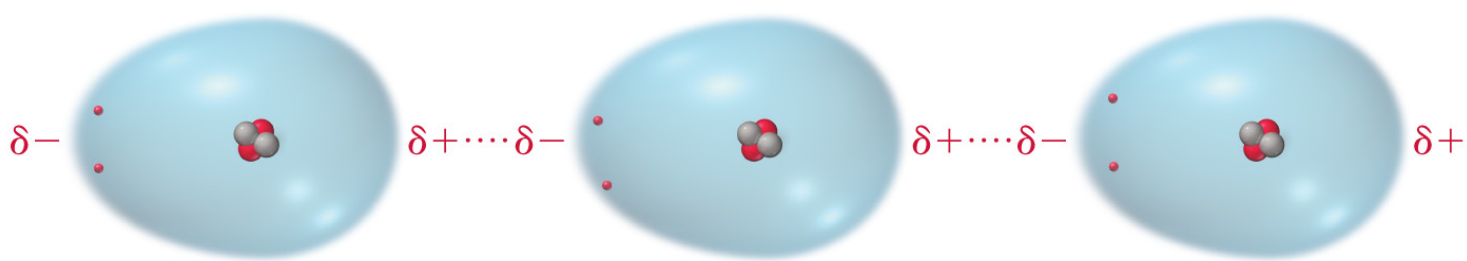
- The attractions between molecules in liquids and solids are called **intermolecular forces (IMFs)**.
- In general, IMFs are due to an attraction between a partial charge on one molecule with an opposite partial charge on another molecule.
- Because they involve *partial* charges, IMFs are *weaker* than bonding interactions.
- The strength of IMFs can be measured by the molecule's **boiling point**. Higher b.p. means more energy is needed to separate molecules, so the IMFs must be stronger.
- We will examine the different types of IMFs in order of **increasing strength**.

## 1. Dispersion Forces (induced dipole / London forces):

- These are the forces between nonpolar molecules or individual atoms (as in Noble Gases).
- Because of the movement of electrons, at any particular time, a molecule may have an instantaneous dipole. This dipole can induce dipoles in nearby molecules, leading to an attraction.

Figure 11.4 **Dispersion Force**

An instantaneous dipole on any one helium atom induces instantaneous dipoles on neighboring atoms, which then attract one another.



# Dispersion Forces (contd):

- Dispersion forces are generally weak, but increase as atoms become larger, due to greater **polarizability**.

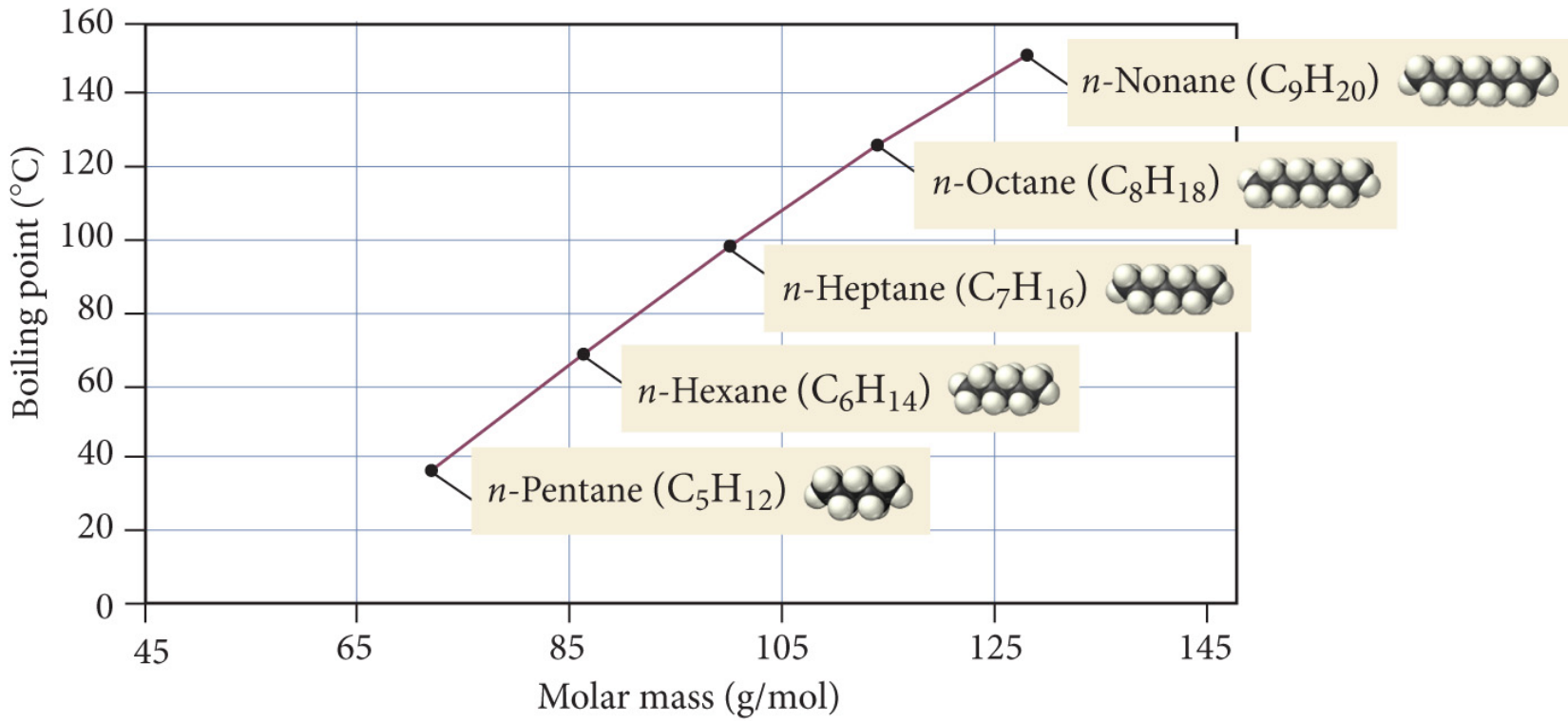
**TABLE 11.3 Boiling Points of the Noble Gases**

| Noble Gas | | Molar Mass (g/mol) | Boiling Point (K) |
|---|---|---|---|
| He |  | 4.00 | 4.2 |
| Ne |  | 20.18 | 27 |
| Ar |  | 39.95 | 87 |
| Kr |  | 83.80 | 120 |
| Xe |  | 131.30 | 165 |

# Dispersion Forces (contd):

- More atoms in a molecule also increases the boiling point:

Figure 11.6



# Dispersion Forces (contd):

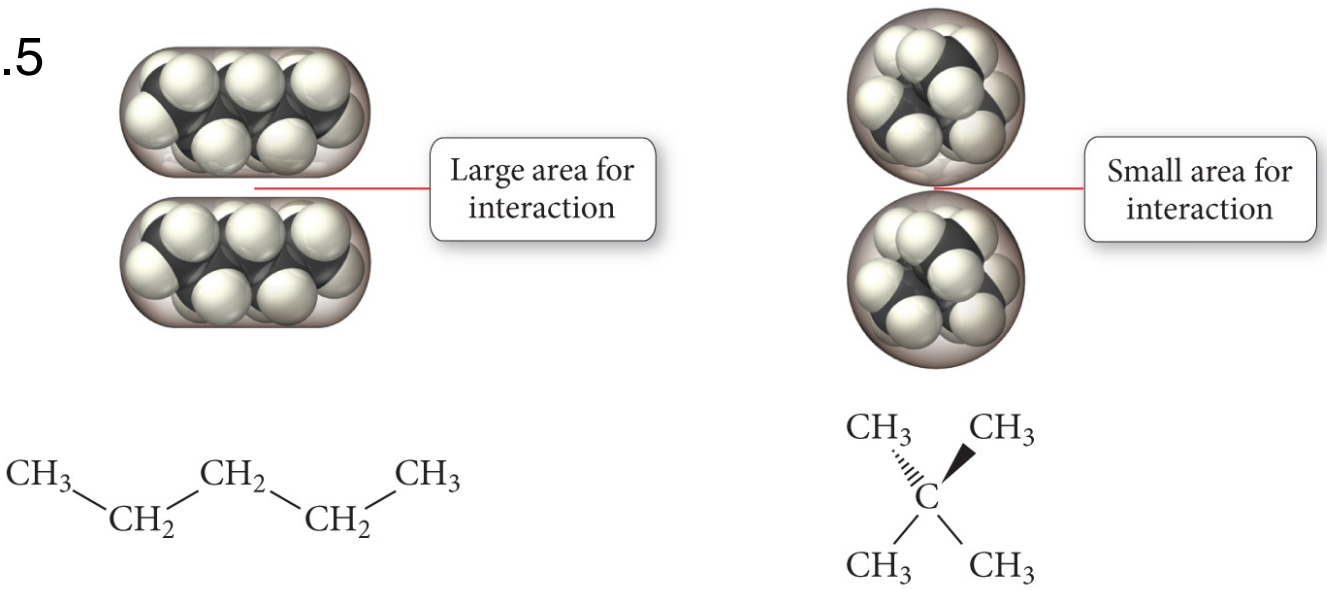
- Effect of shape of molecules: Long molecules have a higher b.p. than molecules with a more compact (spherical) shape due to more points of contact:

***n*-Pentane**
molar mass = 72.15 g/mol
boiling point = 36.1 °C

**Neopentane**
molar mass = 72.15 g/mol
boiling point = 9.5 °C



Figure 11.5



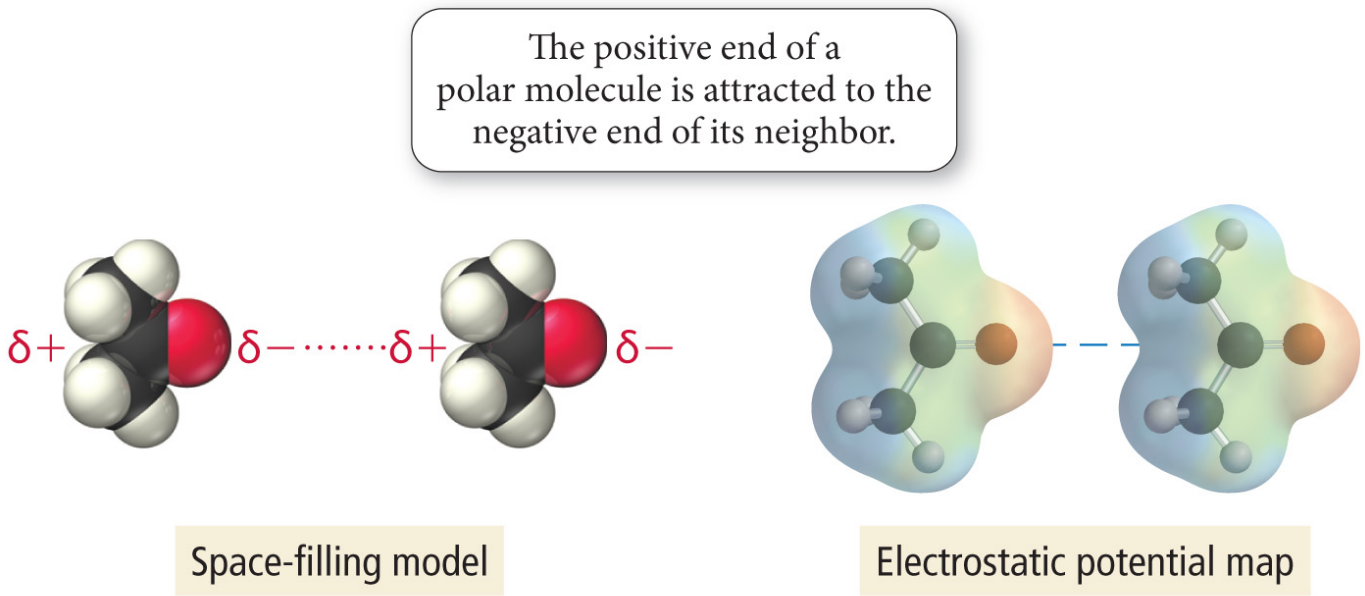

(a) *n*-Pentane

(b) Neopentane

# 2. Dipole – Dipole Forces

- **Polar** molecules have dipole–dipole forces.
- These interactions are stronger than dispersion forces since **dipoles are permanent**.

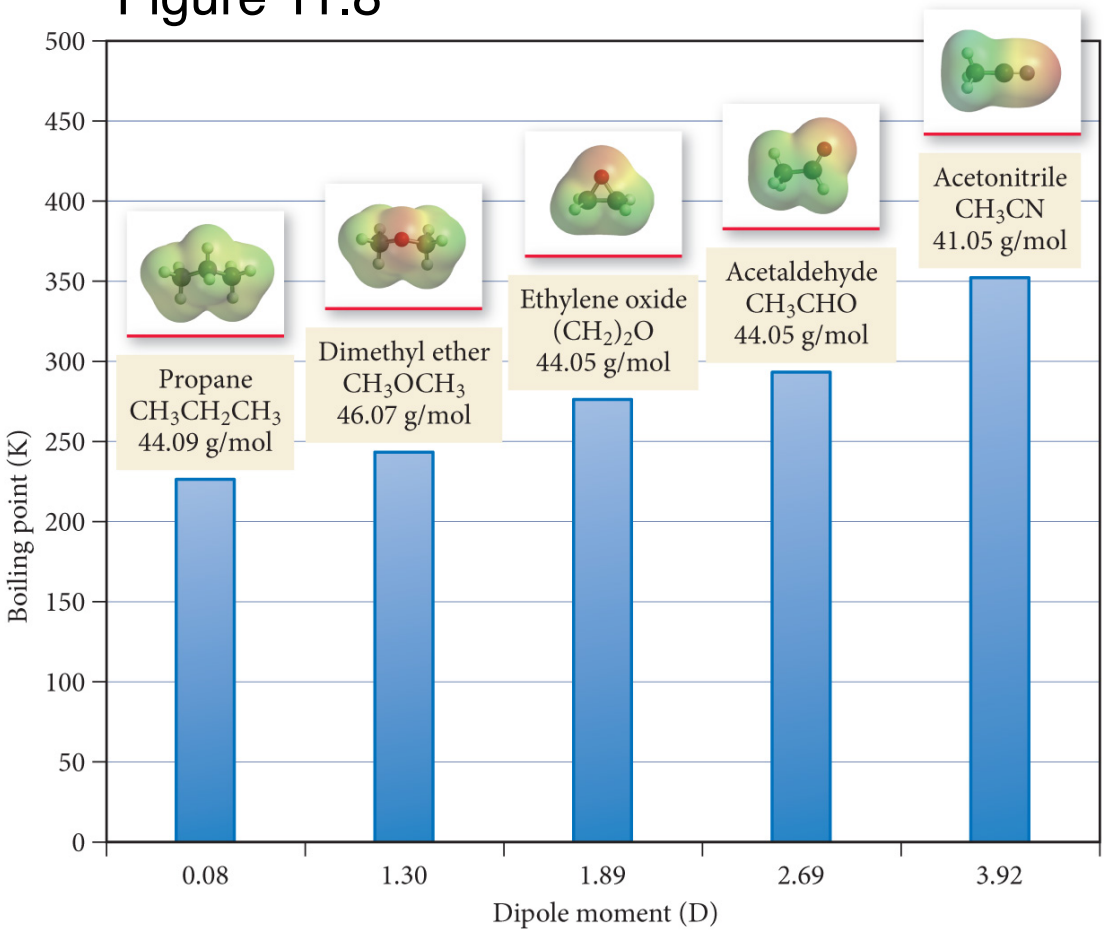
Figure 11.7 **Dipole–Dipole Interaction**



# Dipole – Dipole Forces (contd.)

- For molecules with similar masses, b.p. increases with increasing polarity:

Figure 11.8

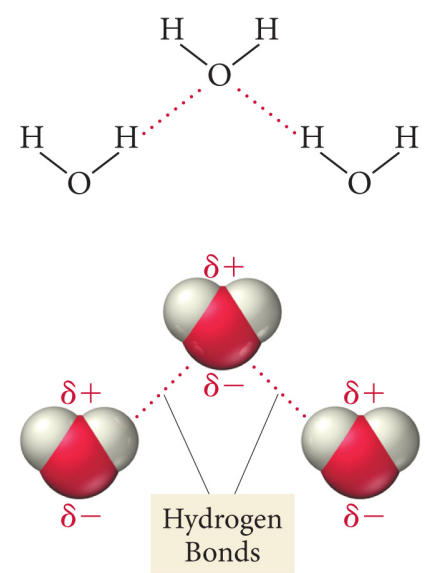


# 3. Hydrogen bonding

- H–bonding is a special type of dipole–dipole force.
- A hydrogen atom covalently bonded to a highly EN atom (N, O or F) can have an especially strong interaction with a lone pair on another very EN atom.

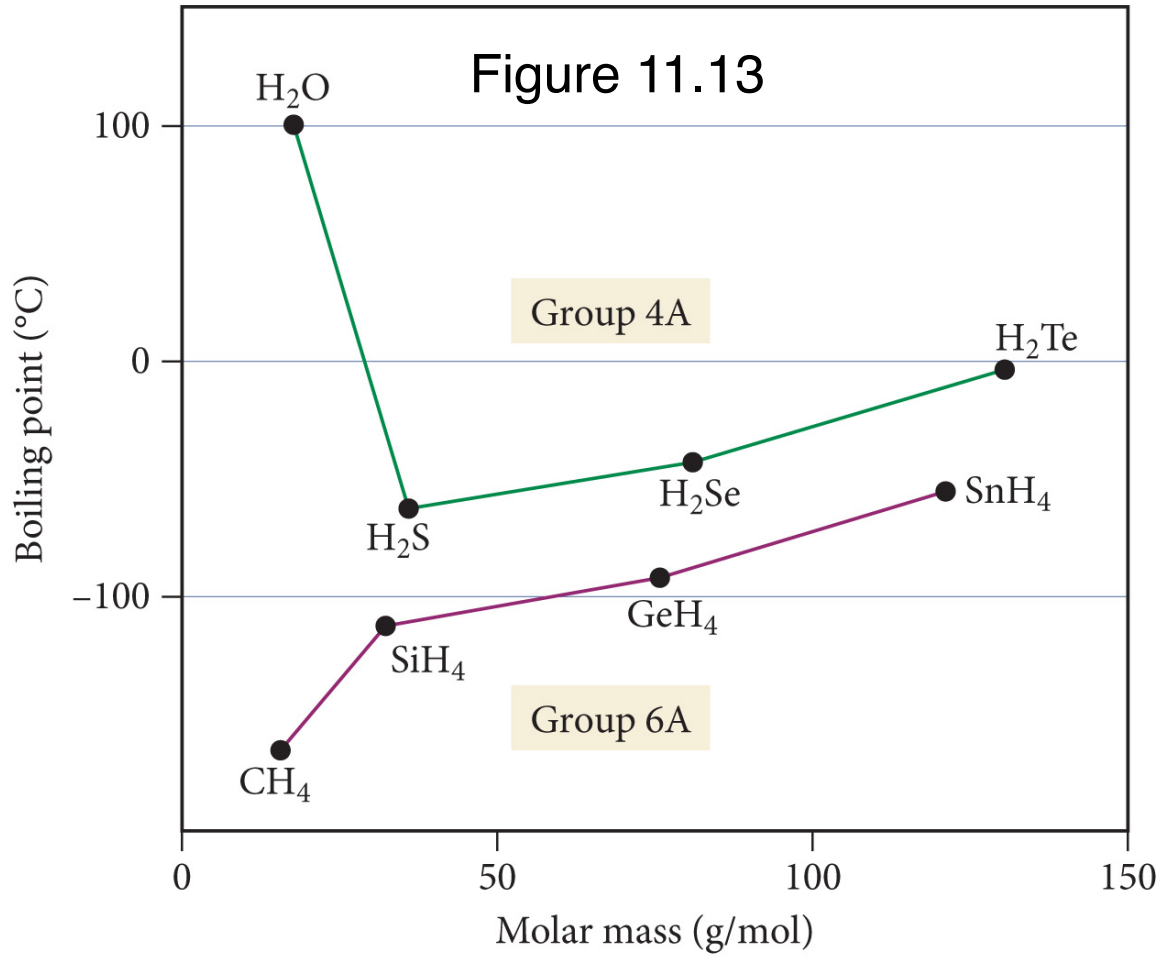
Figure 11.12

**Hydrogen Bonding in Water**



# Hydrogen bonding (contd.)

- Molecules with H-bonding will have a higher b.p. than would be expected otherwise:



# Hydrogen bonding in DNA

Figure 11.16

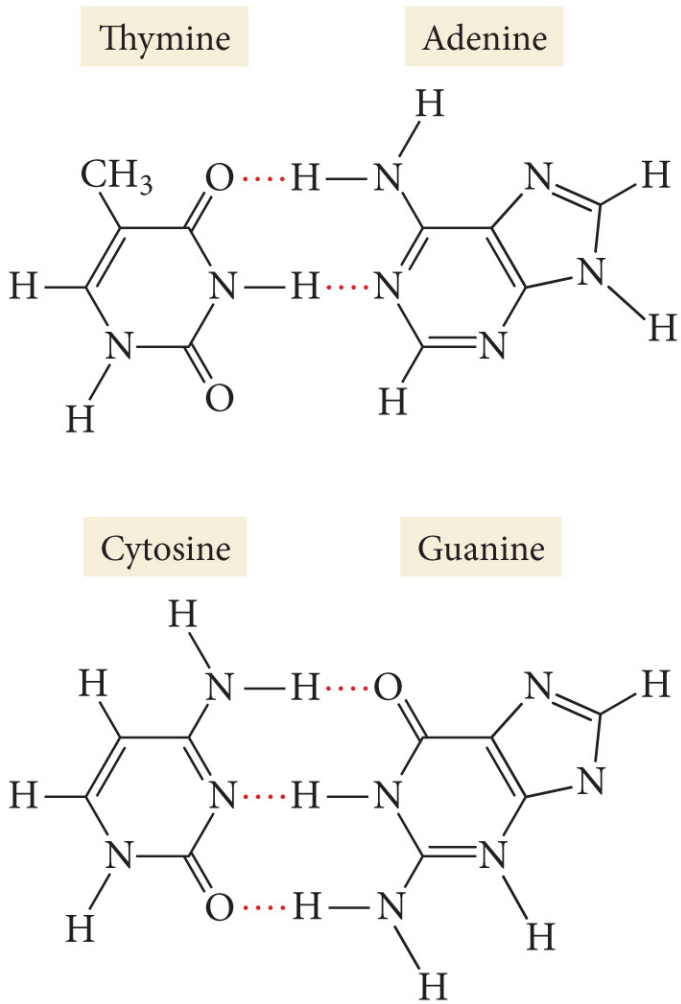
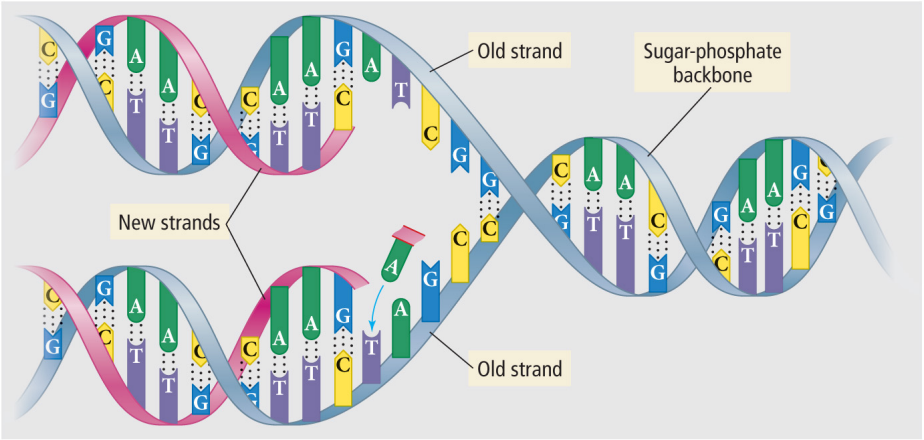





Figure 11.17

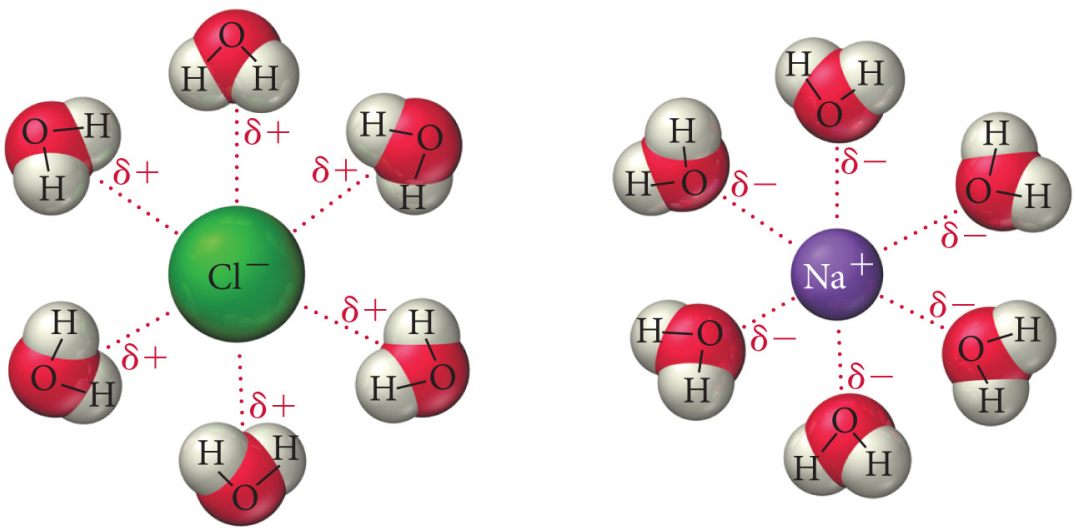


# 4. Ion – Dipole Forces

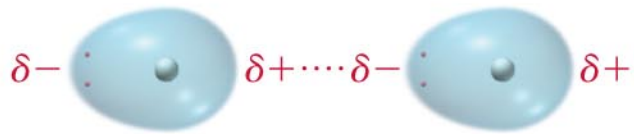
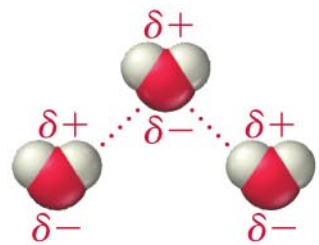
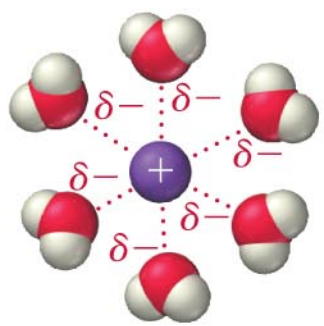
- Ion–dipole forces exist between an ion and a polar molecule, *e.g.* an ionic compound dissolved in water.
- They are even stronger than hydrogen bonds.

Figure 11.14 **Ion–Dipole Forces**

The positively charged end of a polar molecule such as $H_2O$ is attracted to negative ions and the negatively charged end of the molecule is attracted to positive ions.



## TABLE 11.4 Types of Intermolecular Forces

| Type | Present in | Molecular perspective | Strength |
|---|---|---|---|
| Dispersion | All molecules and atoms |   | |
| Dipole–dipole | Polar molecules |   | |
| Hydrogen bonding | Molecules containing H bonded to F, O, or N |   | |
| Ion–dipole | Mixtures of ionic compounds and polar compounds |   | |

# Summary

- How to determine the most important (strongest) IMF for a certain compound:

1. Draw Lewis structure
2. Use VSEPR to determine molecular shape
3. Is the molecule polar?