Chapter 11 (Sections 1–9 only)

Intermolecular Forces

Chemical Forces

Bonding:
- Ionic
- Covalent

Nonbonding:
- Intermolecular forces

Intermolecular Forces

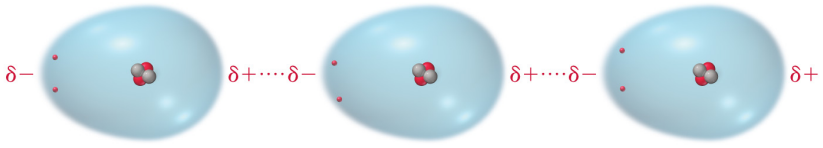
- The attractions between molecules in liquids and solids are called **intermolecular forces (IMFs)**.
- In general, IMFs are due to an attraction between a partial charge on one molecule with an opposite partial charge on another molecule.
- Because they involve *partial* charges, IMFs are *weaker* 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.

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.

Dispersion Force

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

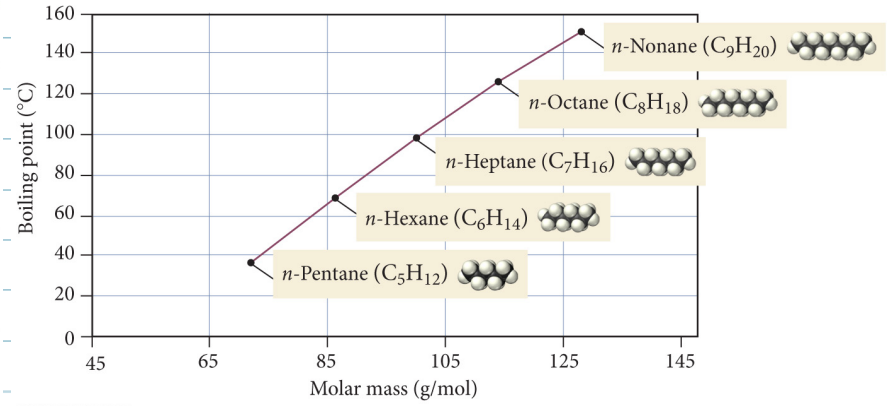


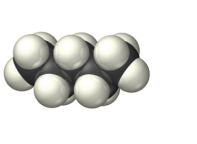
- Dispersion forces are generally weak, but increase as atoms become larger, due to greater **polarizability**.
- Also more atoms in a molecule increases the boiling point (*e.g.* hydrocarbons, Figure 11.6).
- Effect of shape of molecules: Long molecules have a higher b.p. than molecules with a more compact (spherical) shape due to more points of contact.

strength of dispersion forces ↓ Cl_2) liquid, Br_2) liquid, I_2) solid

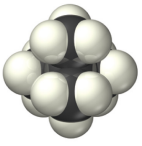
TABLE 11.3 Boiling Points of the Noble Gases

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

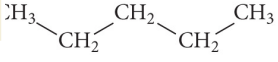




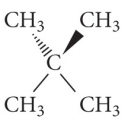
***n*-Pentane**
molar mass = 72.15 g/mol
boiling point = 36.1 °C



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



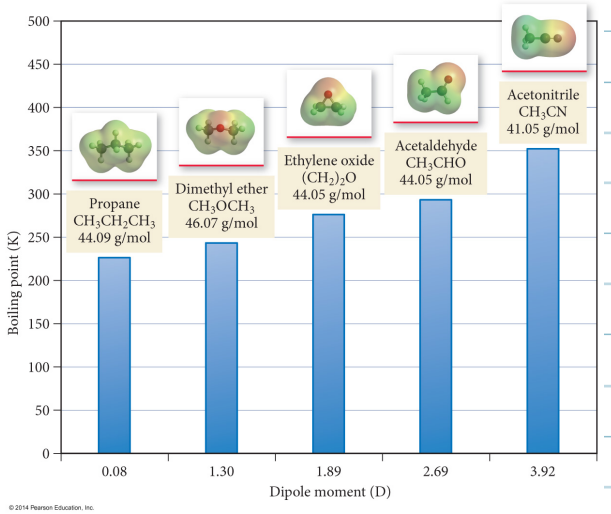
(a) ***n*-Pentane**



(b) **Neopentane**

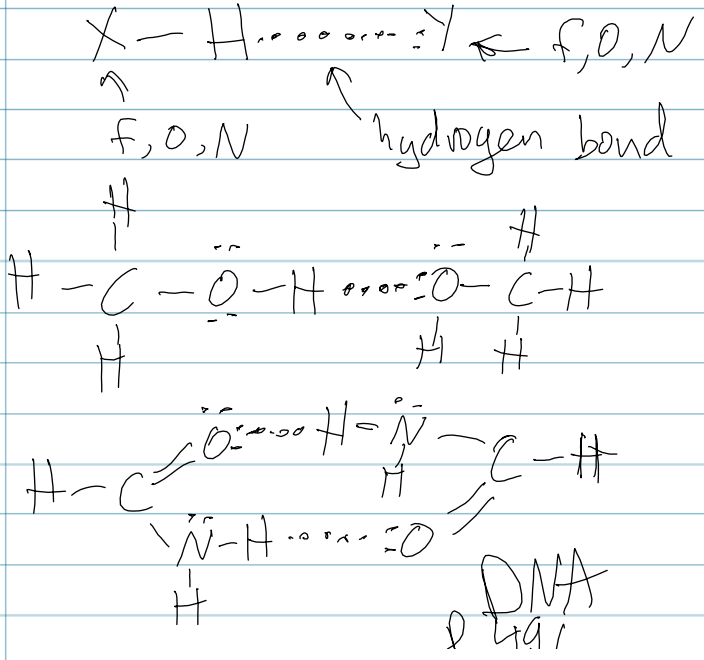
2. Dipole – Dipole Forces

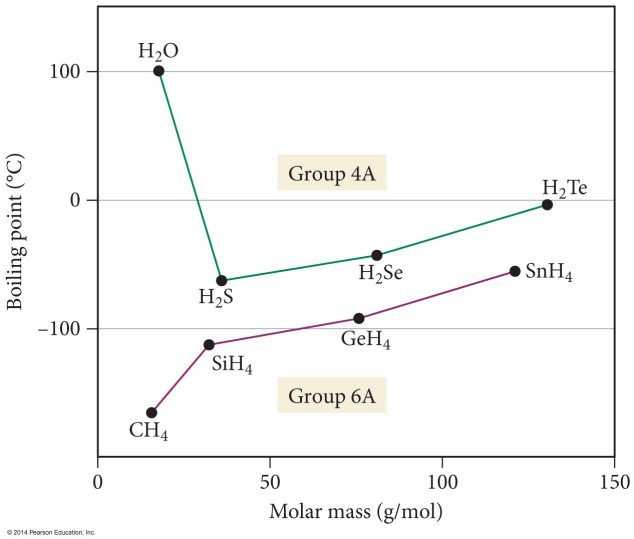
- **Polar** molecules have dipole–dipole forces.
- These interactions are stronger than dispersion forces since **dipoles are permanent**. Thus, a polar molecule will have a higher b.p. than a non-polar molecule with a similar mass.



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.
- Molecules with H-bonding will have a higher b.p. than would be expected otherwise (see Figure 11.13).





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.

Summary:

- What is 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?

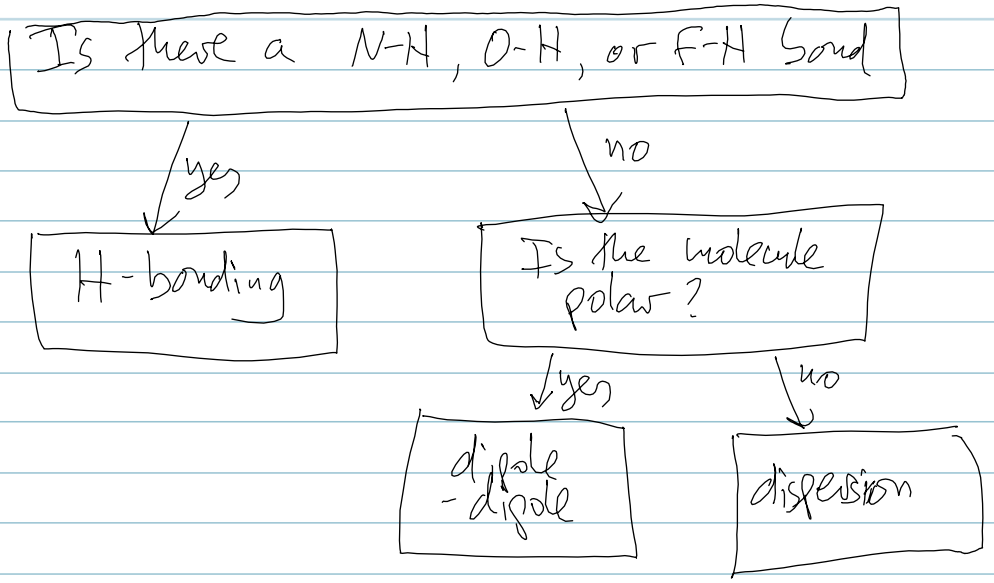
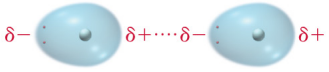
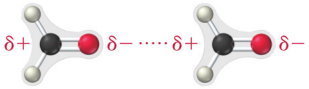
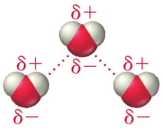


TABLE 11.4 Types of Intermolecular Forces

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