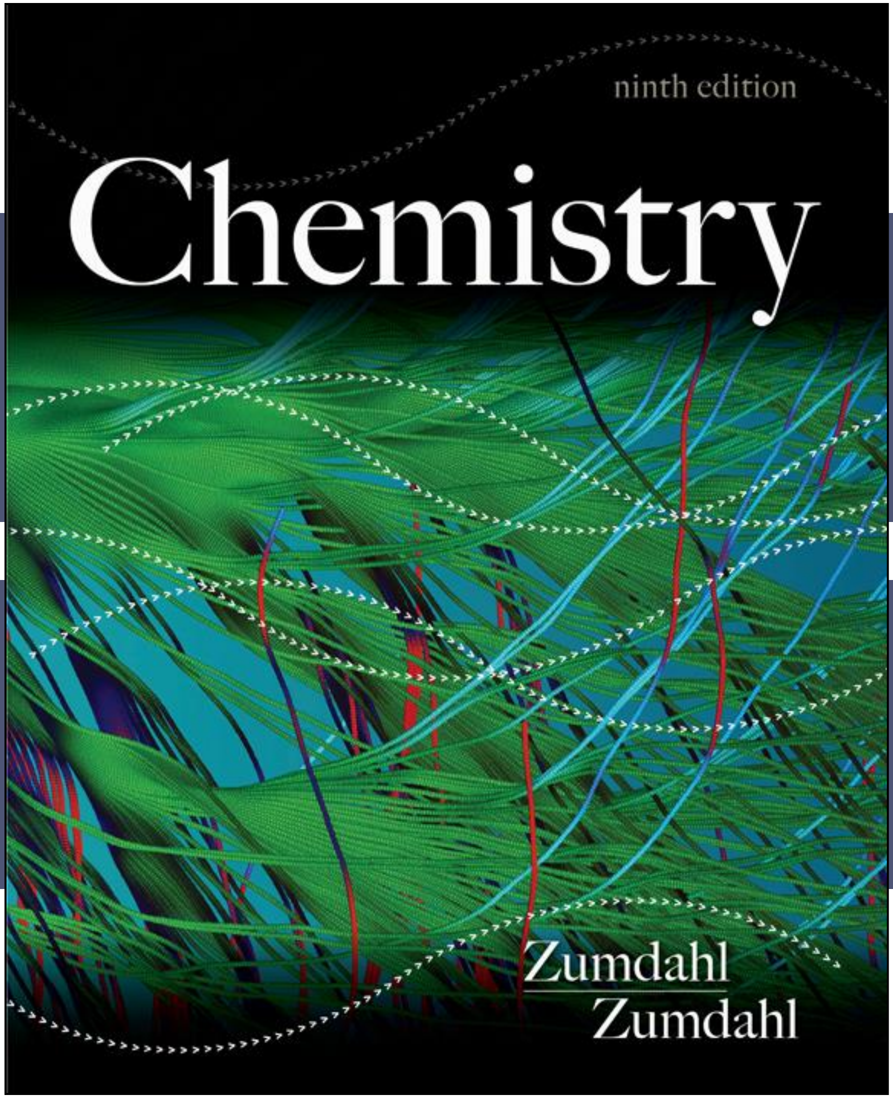


Chapter 10

Liquids and Solids

Changes in States

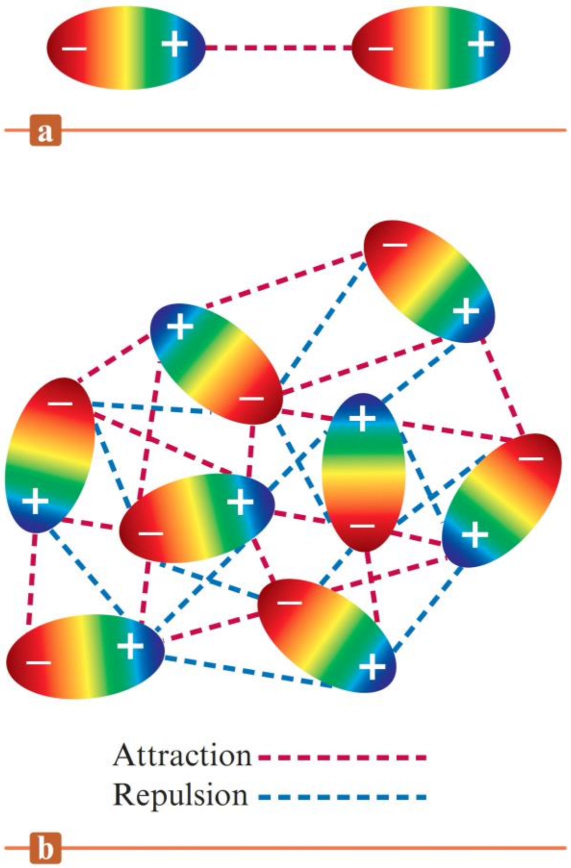
- When a substance changes from solid to liquid to gas, the molecules remain intact
- Caused by the changes in the forces among the molecules and not within the molecules

Dipole–Dipole Forces

- Forces that act between polar molecules
- **Dipole–dipole attraction**: Electrostatic attraction between molecules with dipole moments

Characteristics of Dipole–Dipole Forces

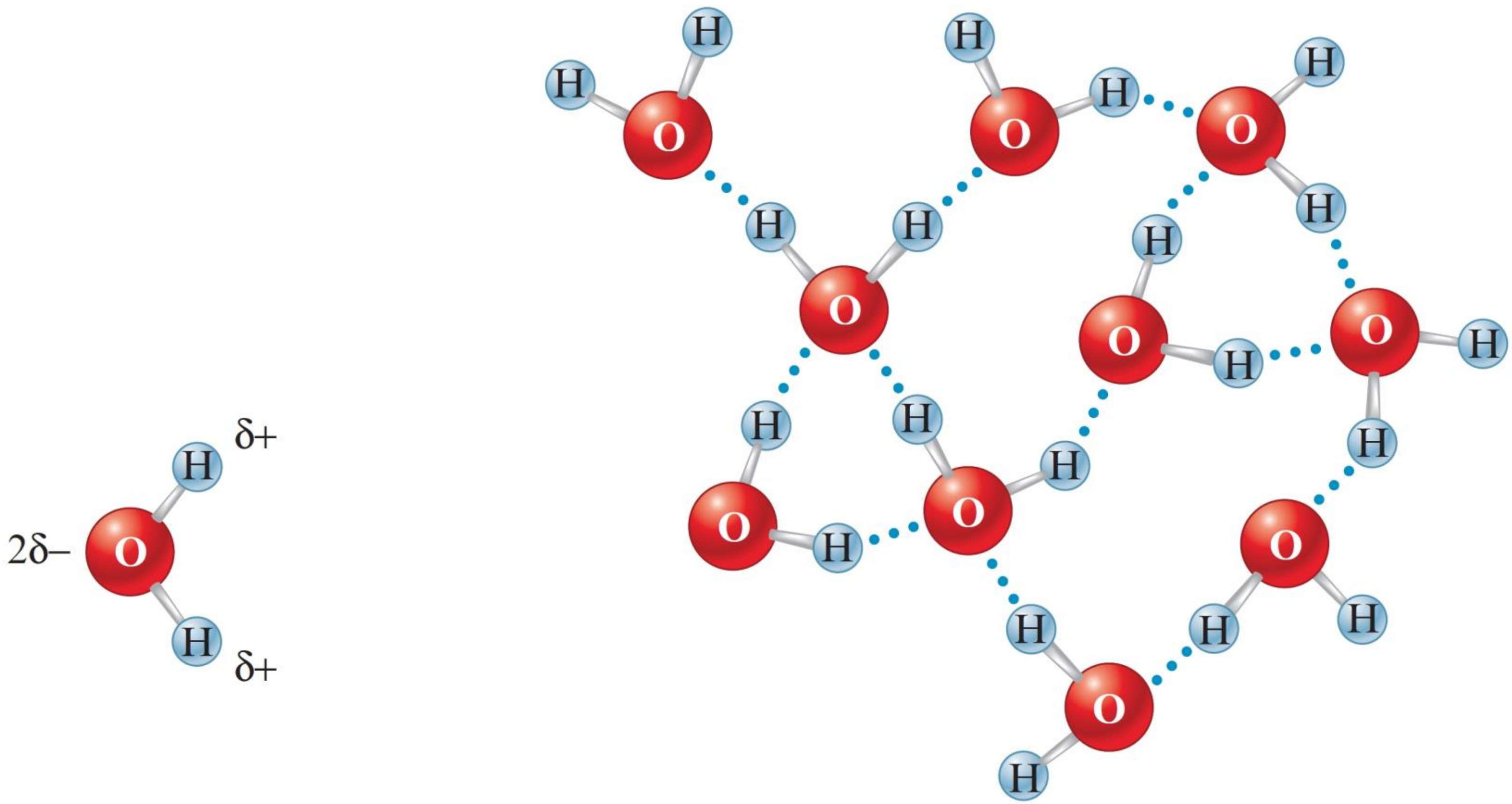
- Strength of the forces decreases as the distance between the dipoles increases



Hydrogen Bonding

- Significantly strong dipole–dipole forces
- Prevalent in molecules that have a hydrogen atom bound to a highly electronegative atom
- Influences physical properties of molecules

Figure 10.3 - Hydrogen Bonding in Water



London Dispersion Forces

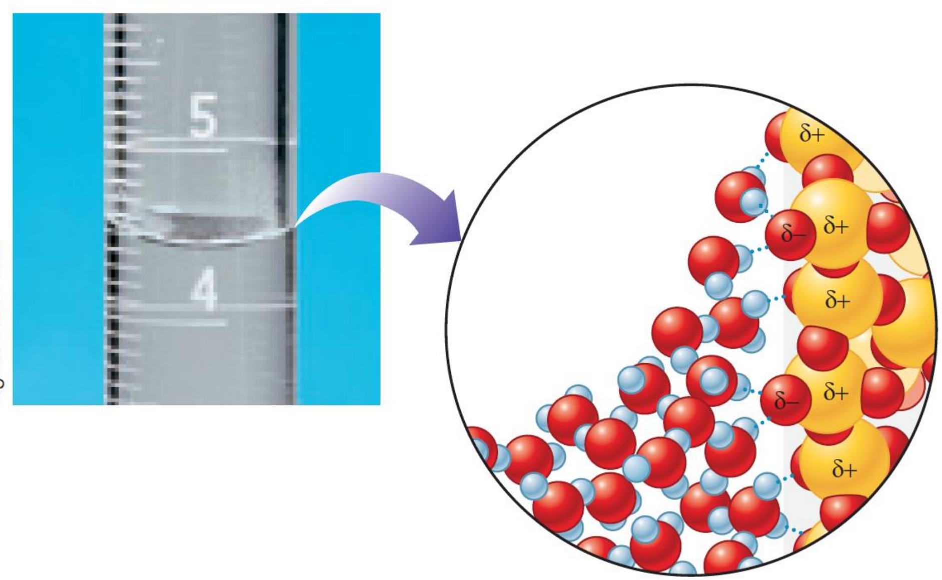
- Forces that exist among noble gas atoms and nonpolar molecules
- Instantaneous dipole
- Can induce a similar dipole in a neighboring atom

Answer with your partner, then compare with another group

- You have learned the difference between intermolecular forces and intramolecular bonds
  - What if intermolecular forces were stronger than intramolecular bonds?
    - What differences could you observe in the world?

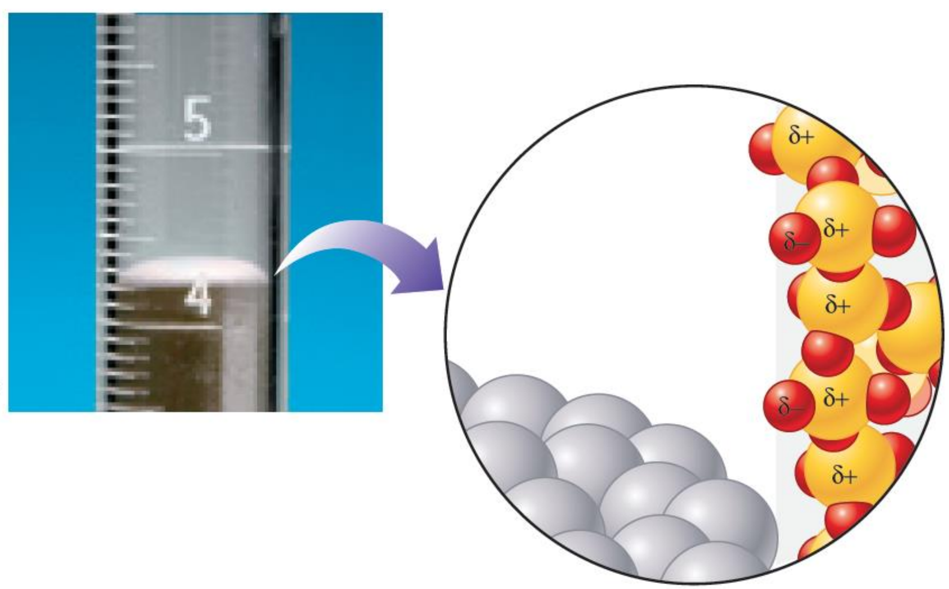
Concave Meniscus Formed by Polar Water

- Adhesive forces toward glass are stronger than cohesive forces in the liquid



Convex Meniscus Formed by Nonpolar Liquid Mercury

- Cohesive forces in the liquid are stronger than adhesive forces toward glass



Classification of Solids

- **Amorphous solids**: Have considerable disorder in their structures
- **Crystalline solids**: Characterized by highly regular arrangement of components
  - **X-ray diffraction**: Helps determine the structures of crystalline solids

Types of Crystalline Solids

- **Ionic solids**: Possess ions at the lattice points that describe the structure of the solid
- **Molecular solids**: Possess discrete covalently bonded molecules at the lattice points
- **Atomic solids**: Possess atoms at the lattice points that describe the structure of the solid

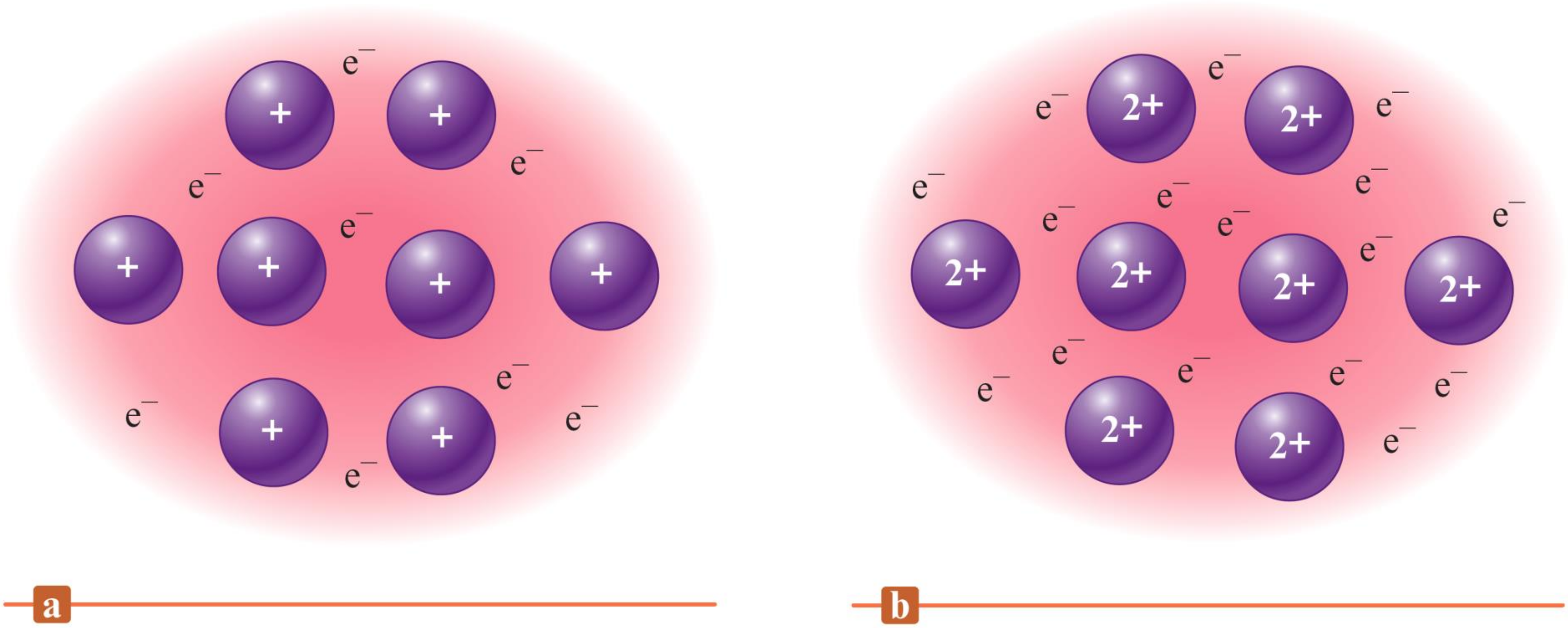
Classification of Atomic Solids

- Metallic solids
- Network solids - Possess atoms bonded by strong directional covalent bonds
- Group 8A solids – Noble gas elements attracted to each other by London dispersion forces

Bonding Models for Metals

- A successful bonding model for metals must consider:
  - Malleability
  - Ductility
  - Efficient and uniform conduction

Figure 10.8 (a) and (b) - Depiction of Electron Sea Model



Representation of an alkali metal (Group 1A) with one valence electron

Representation of an alkaline earth metal (Group 2A) with two valence electrons

Network Solids

- Atomic solids
  - Contain directional covalent bonds
  - Form solids that are viewed as giant molecules
- Properties
  - Brittle in nature
  - Ineffective conductors of heat and electricity

Figure 10.22 (a) - The Structure of Diamond

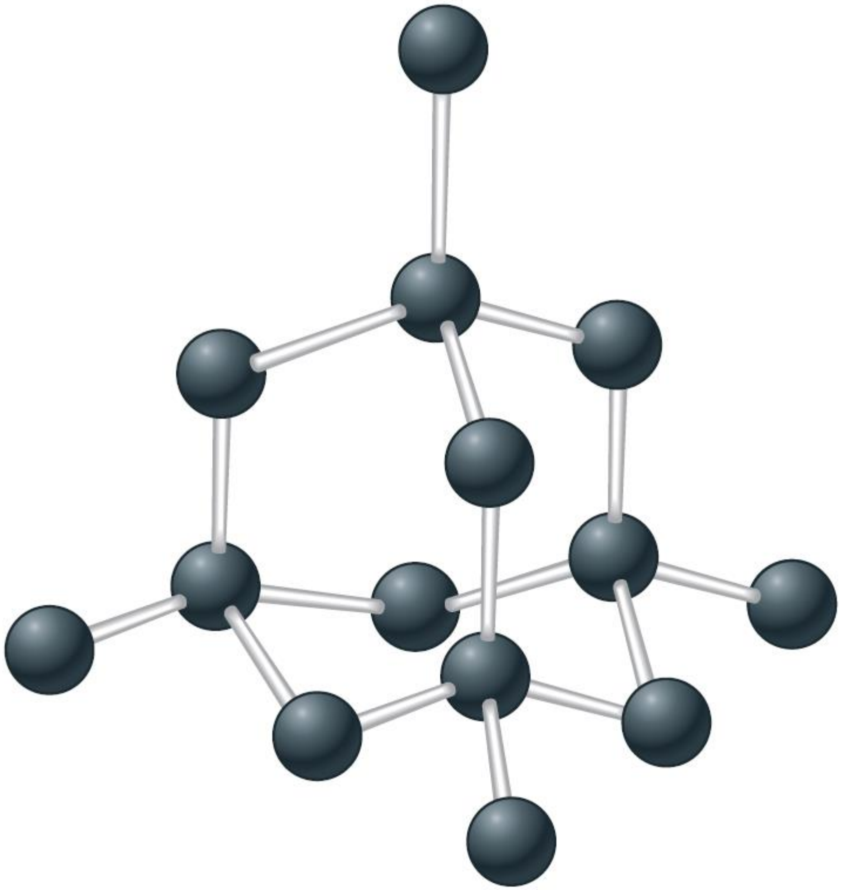


Figure 10.22 (b) - The Structure of Graphite

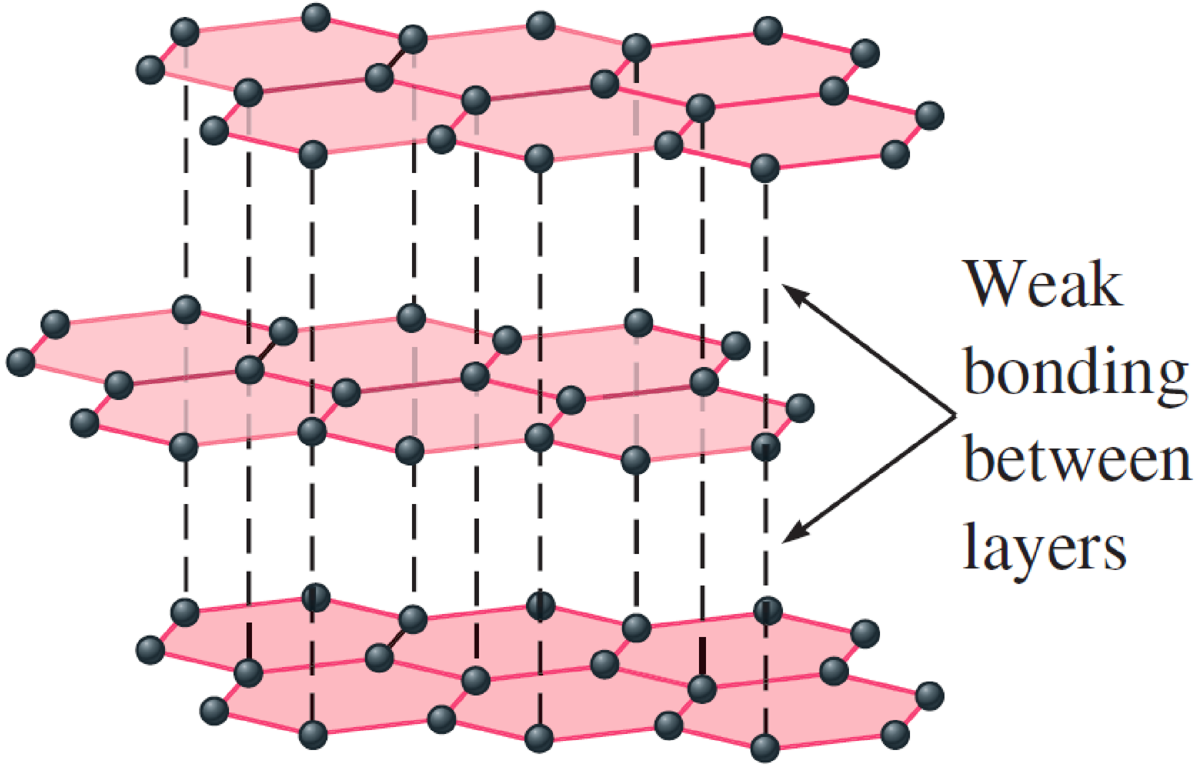


Figure 10.24 (a) and (b) - The *p* Orbitals and the π-Bonding Network in Graphite

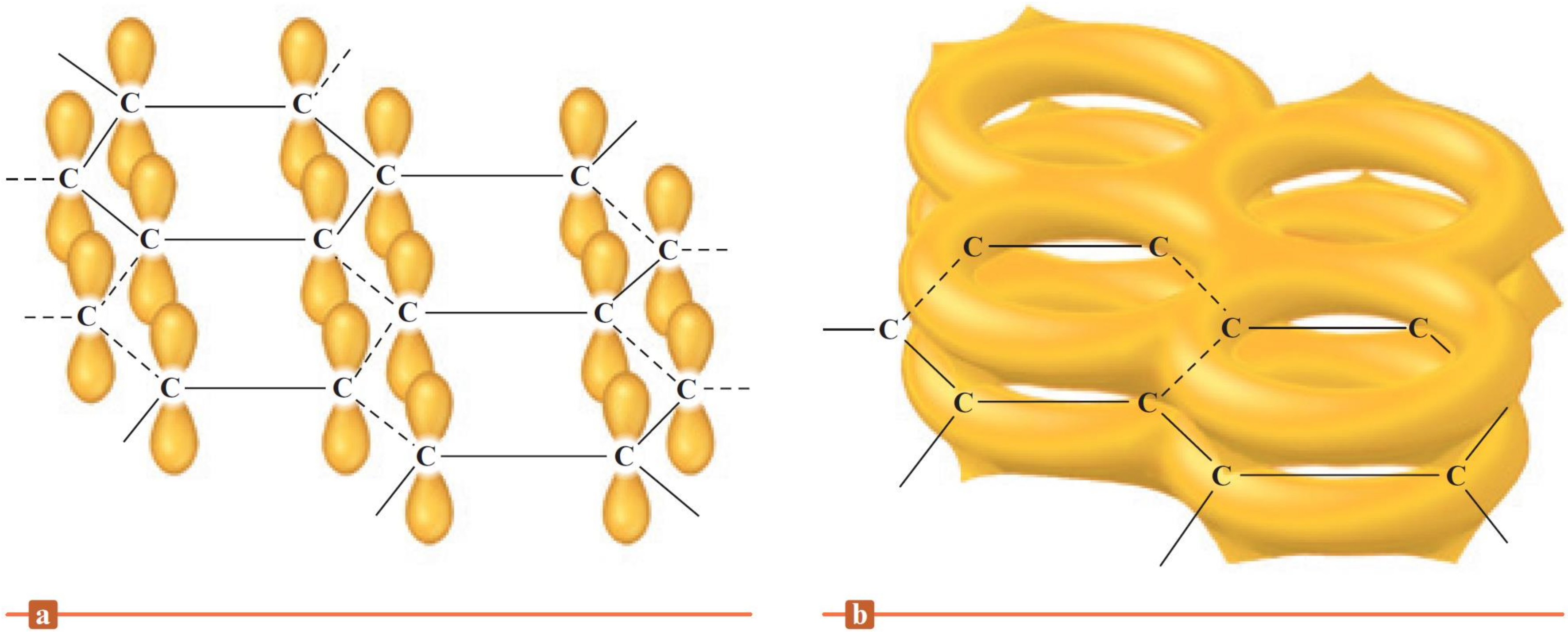


Figure 10.26 - Structure of Quartz

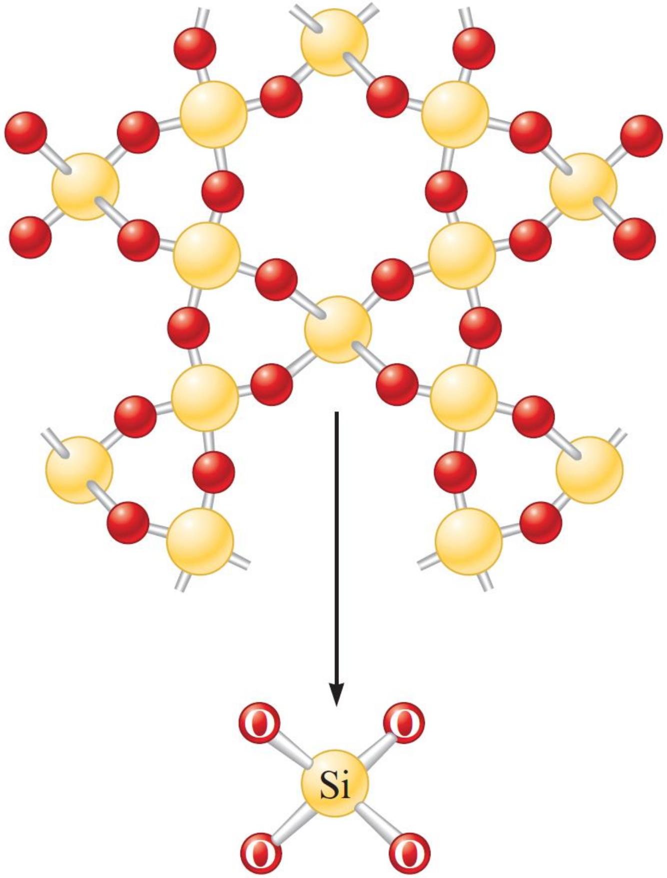
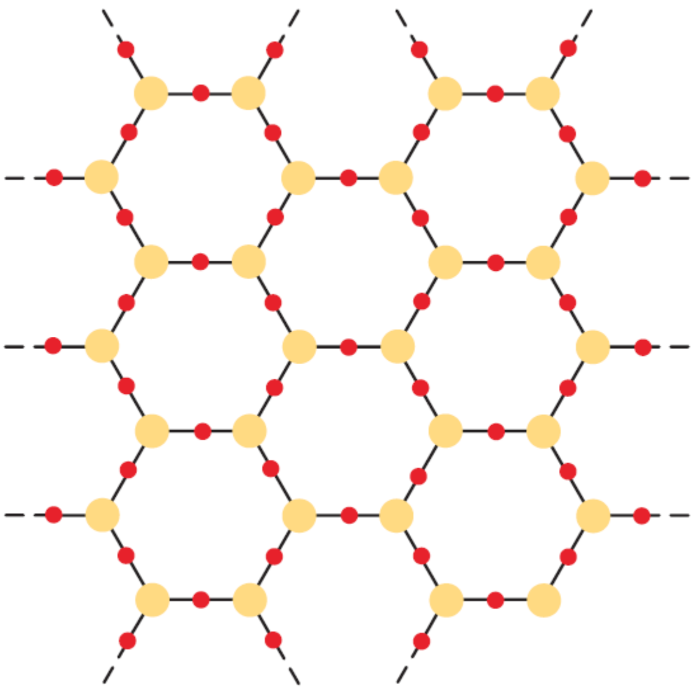
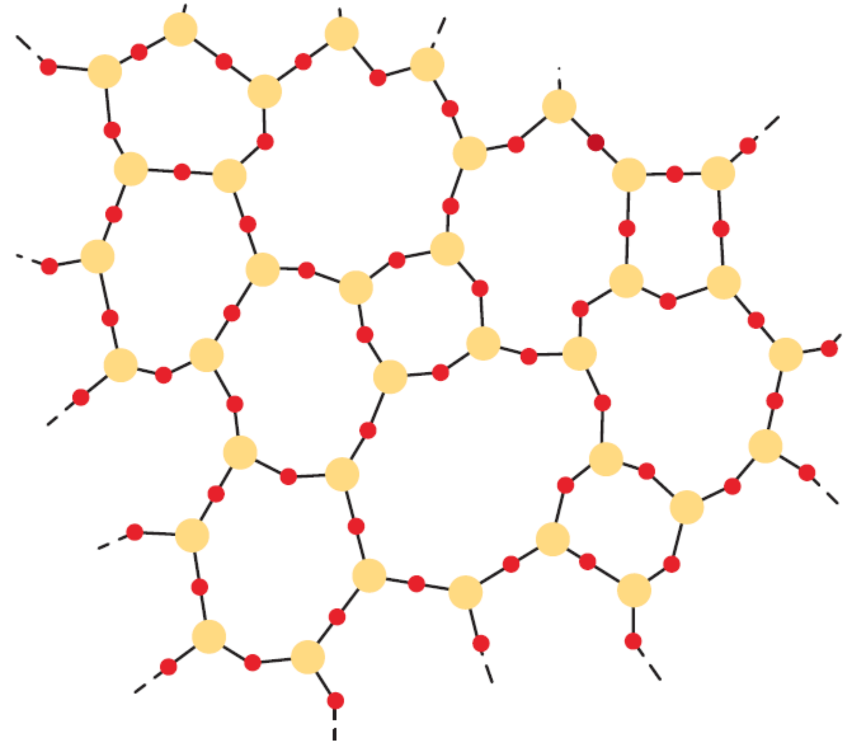


Figure 10.28 (a) and (b) - Two-Dimensional Representations of Quartz Crystal and Quartz Glass



Quartz Crystal



Quartz Glass

Molecular Solids

- Strong covalent bonding within molecules and weak bonding between molecules
- IMFs depend on the nature of the molecules
  - Molecules without a dipole moment possess London dispersion forces
  - Molecules with dipole moments have greater intermolecular forces

Answer in your notes, compare with partner

- Using the Table 10.7, classify each of the following substances according to the type of solid it forms
  a. Gold
  b. Carbon dioxide
  c. Lithium fluoride
  d. Krypton

Interactive Example 10.4 - Solution

a. Solid gold is an atomic solid with metallic properties
b. Solid carbon dioxide contains nonpolar carbon dioxide molecules and is a molecular solid
c. Solid lithium fluoride contains Li^+ and F^- ions and is a binary ionic solid

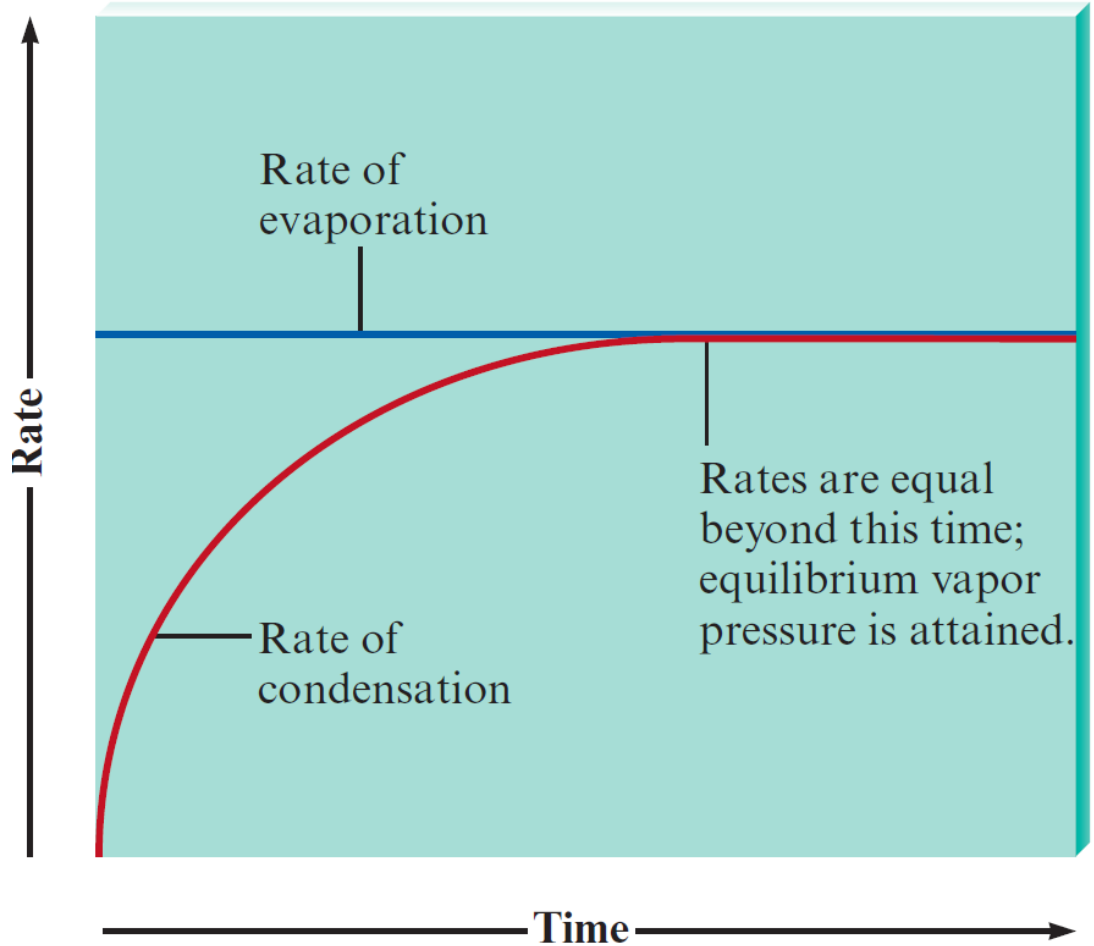
Interactive Example 10.4 - Solution (Continued)

d. Solid krypton contains krypton atoms that can interact only through London dispersion forces
   - It is an atomic solid but has properties characteristic of a molecular solid with nonpolar molecules

Vaporization (Evaporation)

- Molecules of a liquid escape surface to form a gas
- **Heat of vaporization (ΔH_{vap})**: Energy required to vaporize 1 mole of a liquid at a pressure of 1 atm
- Endothermic process

Figure 10.37 - Rates of Condensation and Evaporation



Answer with partner, compare with another group

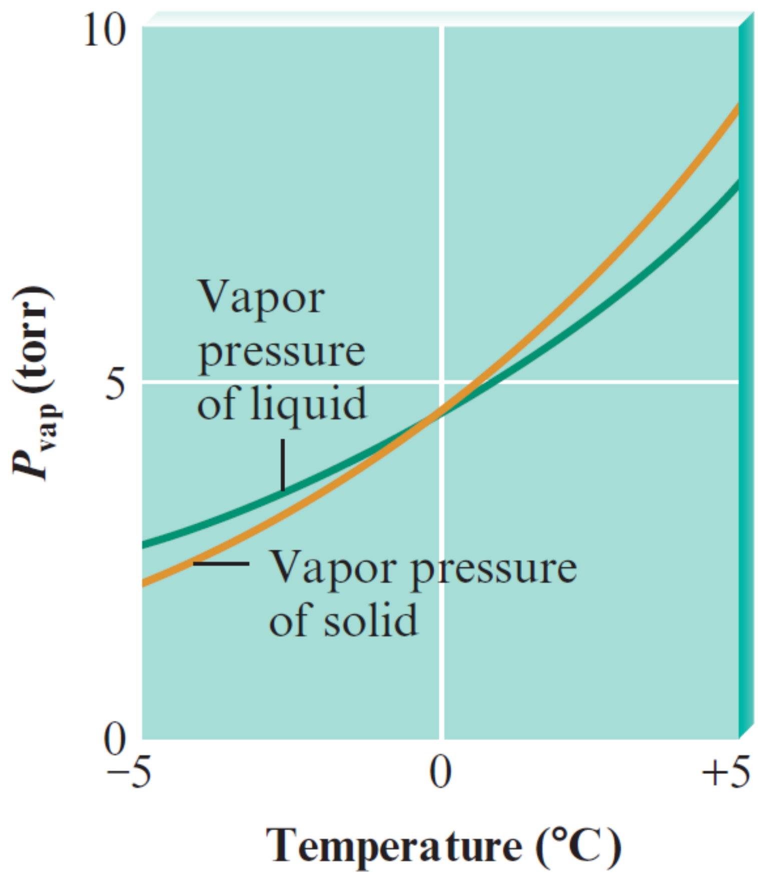
- You have seen that the water molecule has a bent shape and therefore is a polar molecule
  - This accounts for many of water's interesting properties
  - What if the water molecule was linear?
    - How would this affect the properties of water, such as its surface tension, heat of vaporization, and vapor pressure?
    - How would life be different?

Vapor Pressure and Liquids

- Liquids with high vapor pressures are volatile
- The size of the intermolecular forces in a liquid determines its vapor pressure
  - Substances with large molar masses have relatively low vapor pressures
- Vapor pressure increases significantly with temperature

Melting Point

- The temperature at which the solid and liquid have identical vapor pressures



Temperature and Vapor Pressure - Case 1

- Temperature at which the vapor pressure of the solid is greater than that of the liquid
  - The solid releases vapor
  - The liquid absorbes vapor
  - Net effect - Conversion from solid to liquid
    - Temperature would be above the melting point of ice

Temperature and Vapor Pressure - Case 2

- Temperature at which vapor pressure of the solid is less than that of the liquid
  - Liquid will disappear, amount of ice will increase
    - Temperature should be below the melting point of ice

Temperature and Vapor Pressure - Case 3

- Temperature at which the vapor pressures of the solid and liquid are identical
  - **Normal melting point**: Temperature at which the vapor pressures of the solid and liquid states are identical at 1 atmosphere
  - **Normal boiling point:** Temperature at which the vapor pressure of the liquid is 1 atmosphere