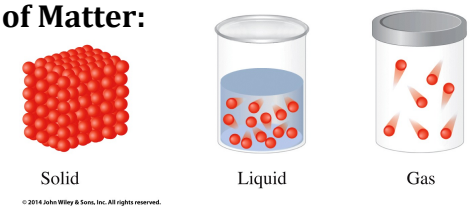
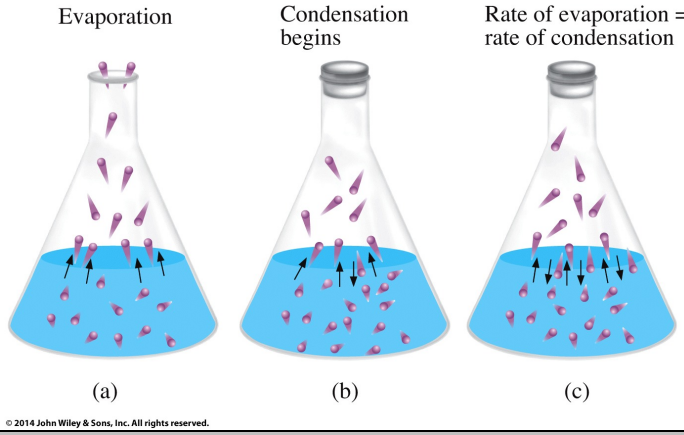
Chapter 13
Liquids
Advanced Chemistry

13.1 State of Matter: A Review



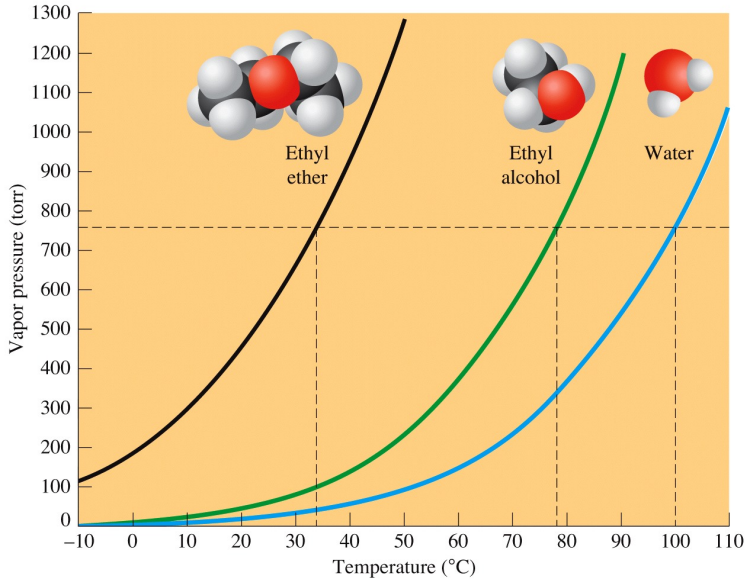
13.2 Properties of Liquids

Learning Objective	
Explain why liquids tend to form drops and explain the process of evaporation and its relationship to vapor pressure.	• The resistance of a liquid to increase in its surface area is the surface tension of the liquid. Liquids form drops because liquids have surface tension. • During evaporation, molecules of greater-than-average kinetic energy escape from the liquid. Vapor pressure is the pressure exerted by a vapor in equilibrium with its liquid, in other words the measure of the "escaping" tendency of molecules to go from the liquid to the vapor state.

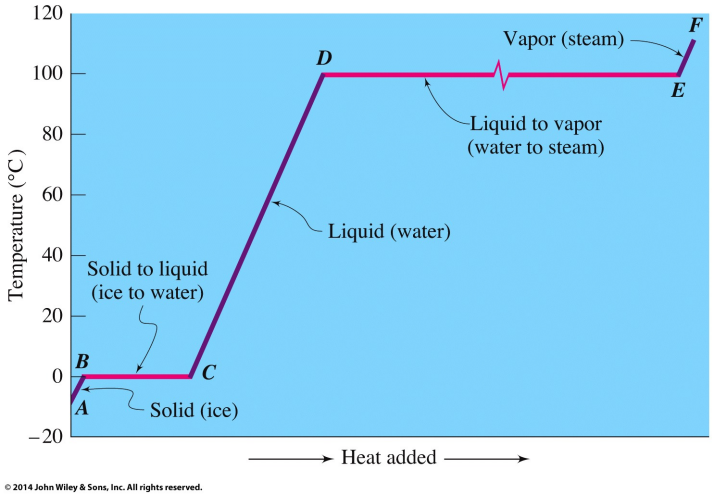


Key Terms	
Surface tension	The resistance of a liquid to an increase in its surface area.
Capillary action	The spontaneous rising of a liquid in a narrow tube, which results form the cohesive forces within the liquid and the adhesive forces between the liquid and the walls of the container.
Meniscus	The shape of the surface of a liquid when placed in a glass cylinder. It can be concave or convex.
Evaporation	The escape of molecules from the liquid state to the gas or vapor state.
Vaporization	See evaporation.
Sublimation	The process of going directly from the solid state to the vapor state without becoming a liquid.
Condensation	The process by which molecules in the gaseous state return to the liquid state.
Vapor pressure	The pressure exerted by a vapor in equilibrium with its liquid.
Volatile	A substance that evaporates readily; a liquid with a high vapor pressure and a low boiling point.

13.3 Boiling Point and Melting Point

Learning Objective	
Define boiling point and melting point and determine the boiling point of a liquid from a graph of temperature versus vapor pressure.	• The boiling point of a liquid is the temperature at which its vapor pressure equals the atmosphere pressure. At 1 atm the boiling point is called the normal boiling point for a liquid. • The temperature at which a solid is in equilibrium with its liquid phase is the freezing point or melting point. 
Key Terms	
Boiling point	The temperature at which the vapor pressure of a liquid is equal to the pressure above the liquid. It is called the normal boiling point when the pressure is 1 atmosphere.
Normal boiling point	The temperature at which the vapor pressure of a liquid equals 1 atm or 760 torr pressure.
Vapor pressure curve	A graph generated by plotting the temperature of a liquid on the *x*-axis and it vapor pressure on the *y*-axis. Any point on the curve represents an equilibrium between the vapor and liquid.
Melting point (or freezing point)	The temperature at which the solid and liquid states of a substance are in equilibrium.

13.4 Changes of State

Learning Objective	
Calculate the amount of energy involved in a change of state.	 • *Solid (ice).* As energy flows into the ice, the vibrations within the crystal increase and the temperature rises (A→B). • *Solid to liquid (ice to water).* Eventually, the molecules begin to break free form the crystal and melting occurs (B→C). During the melting process, all energy goes into breaking down the crystal structure; the temperature remains constant. The energy required to change exactly one gram of a solid at its melting point into a liquid is called the heat of fusion. • *Liquid (water).* When the solid has completely melted, the temperature once again rises (C→D); the energy input is increasing the molecular motion within the water. • *Liquid to vapor (water to steam).* At 100°C, the water reaches its boiling point; the temperature remains constant while the added energy is used to vaporize the water to steam (D→E). The heat of vaporization is the energy required to change exactly one gram of liquid to vapor at its normal boiling point. The attractive forces between the liquid molecules are overcome during vaporization. • *Vapor (steam).* Beyond this temperature, all the water exists as steam and is being heated further (E→F).
Key Terms	
Heat of fusion	The energy required to change 1 gram of a solid into a liquid at its melting point.
Heat of vaporization	The amount of heat required to change 1 gram of liquid to a vapor at its normal boiling point.

13.5 Intermolecular Forces

Learning Objective	
Describe the tree types of intermolecular forces and explain their significance.	• Dipole-dipole attractions among polar molecules. • A hydrogen bond is the dipole-dipole attraction between polar molecules containing any of these types of bonds: F—H, O—H, N—H. • London dispersion forces cause attractions among nonpolar atoms and molecules.
Key Terms	
Intermolecular forces	Forces of attraction between molecules.
Intramolecular forces	Forces of attraction within a molecule, for example a covalent bond.
Dipole-dipole attractions	Forces of attraction between polar molecules as a result of the dipole moment within each molecule.
Hydrogen bond	The intermolecular force acting between molecules that contain hydrogen covalently bonded to the highly electronegative elements F, O, and N.
London dispersion forces	Attractive forces between nonpolar molecules which result from instantaneous formation of dipoles in the electron cloud.

13.6 Hydrates

Learning Objective	
Explain what hydrates are, write formulas for hydrates, and calculate the percent water in a hydrate.	• Solids that contain water molecules as part of their crystalline structure are called hydrates. • Formulas of hydrates are given by writing the formula for the anhydrous compound followed by a dot and then the number of water molecules present. • Using the molar mass of the anhydrous compound and water, as well as the mole ratio of the anhydrous compound to water, the percent water can be determined. $\frac{(mol\ water \times M\ water)}{M\ anydrous\ cmpd + (mol\ water \times M\ water)} \times 100 = \%\ water$
Key Terms	
Hydrate	A solid that contains water molecules as part of its crystalline structure.
Water of hydration	See water of crystallization.
Water of crystallization	Water molecules that are part of a crystalline structure, as in a hydrate; also called water of hydration.

13.7 Water, A Unique Liquid

Learning Objective	
Describe the characteristics of water in terms of its structure and list the sources of drinking water.	• Water is our most common resource, covering 75% of the Earth's surface. • Water is a colorless, odorless, tasteless liquid with a melting point of 0°C and the boiling point of 100°C at 1 atm. • The water molecule consists of 2 H atoms and 1 O atom boded together at a 105° bond angle, making the molecule polar. • Water can be formed in a variety of ways including: reclamation of wastewater, reverse osmosis, desalination, low-temperature distillation, and hydrogen combustion.
Key Term	
Semipermeable membrane	A membrane that allows the passage of water (solvent) molecules through it in ether direction but prevents the passage of larger solute molecules or ions.