Pearson

Chapter Summary and Review

Key Learning Outcomes

CHAPTER OBJECTIVES	ASSESSMENT
Determine Whether a Molecule Has Dipole–Dipole Forces (11.3)	• Example 11.1 For Practice 11.1 Exercises 35, 36, 37, 38
Determine Whether a Molecule Displays Hydrogen Bonding (11.3)	• Example 11.2 For Practice 11.2 Exercises 35, 36, 37, 38
Use the Heat of Vaporization in Calculations (11.5)	• Example 11.3 For Practice 11.3 For More Practice 11.3 Exercises 57, 58, 59, 60
Use the Clausius–Clapeyron Equation (11.5)	• Examples 11.4, 11.5 For Practice 11.4, 11.5 Exercises 61, 62, 63, 64
Navigate Within a Phase Diagram (11.8)	• Example 11.6 For Practice 11.6 Exercises 71, 72, 75, 76
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Key Terms

Section 11.2

crystalline
amorphous

Section 11.3

dispersion force (London force)
dipole–dipole force
permanent dipole
miscibility
hydrogen bonding
hydrogen bond
ion–dipole force

Section 11.4

surface tension

viscosity

capillary action

Section 11.5

vaporization

condensation

volatile

nonvolatile

heat (or enthalpy) of vaporization (ΔH_{vap})

dynamic equilibrium

vapor pressure

boiling point

normal boiling point

Clausius–Clapeyron equation

critical temperature (T_c)

critical pressure (P_c)

Section 11.6

sublimation

deposition

melting point

melting (fusion)

freezing

heat of fusion (ΔH_{fus})

Section 11.8

phase diagram

triple point

critical point

Key Concepts

Solids, Liquids, and Intermolecular Forces (11.1, 11.2, 11.3)

- The forces that hold molecules or atoms together in a liquid or solid are intermolecular forces. The strength of the intermolecular forces in a substance determines its state.
- Dispersion forces are present in all elements and compounds; they arise from the fluctuations in electron distribution within atoms and molecules. Dispersion forces are the weakest intermolecular forces, but they are significant in molecules with high molar masses.
- Dipole–dipole forces, generally stronger than dispersion forces, are present in all polar molecules.
- Hydrogen bonding occurs in polar molecules that contain hydrogen atoms bonded directly to fluorine, oxygen, or nitrogen. These are the strongest intermolecular forces.
- Ion–dipole forces occur when ionic compounds are mixed with polar compounds; they are especially important in aqueous solutions.

Surface Tension, Viscosity, and Capillary Action (11.4)

- Surface tension results from the tendency of liquids to minimize their surface area in order to maximize the interactions between their particles, thus lowering potential energy. Surface tension causes water droplets to form spheres and allows insects and paper clips to temporarily float on the surface of water.
- Viscosity is the resistance of a liquid to flow. Viscosity increases with increasing strength of intermolecular forces and decreases with increasing temperature.
- Capillary action is the ability of a liquid to flow against gravity up a narrow tube. It is the result of adhesive forces, the attraction between the molecules and the surface of the tube, and cohesive forces, the attraction

between the molecules in the liquid.

Vaporization and Vapor Pressure (11.5, 11.7)

- Vaporization, the transition from liquid to gas, occurs when thermal energy overcomes the intermolecular forces present in a liquid. The opposite process is condensation. Vaporization is endothermic, and condensation is exothermic.
- The rate of vaporization increases with increasing temperature, increasing surface area, and decreasing strength of intermolecular forces.
- The heat of vaporization (ΔH_{vap}) is the heat required to vaporize one mole of a liquid.
- In a sealed container, a solution and its vapor come into dynamic equilibrium, at which point the rate of vaporization equals the rate of condensation. The pressure of a gas that is in dynamic equilibrium with its liquid is its vapor pressure.
- The vapor pressure of a substance increases with increasing temperature and with decreasing strength of its intermolecular forces.
- The boiling point of a liquid is the temperature at which its vapor pressure equals the external pressure.
- The Clausius–Clapeyron equation expresses the relationship between the vapor pressure of a substance and its temperature, and we can use it to calculate the heat of vaporization from experimental measurements.
- When a liquid is heated in a sealed container, it eventually forms a supercritical fluid, which has properties intermediate between a liquid and a gas. This occurs at the critical temperature and critical pressure.

Fusion and Sublimation (11.6, 11.7)

- Sublimation is the transition from solid to gas. The opposite process is deposition.
- Fusion, or melting, is the transition from solid to liquid. The opposite process is freezing.
- The heat of fusion (ΔH_{fus}) is the amount of heat required to melt one mole of a solid. Fusion is endothermic.
- The heat of fusion is generally less than the heat of vaporization because intermolecular forces do not have to be completely overcome for melting to occur.

Phase Diagrams (11.8)

- A phase diagram is a map of the states of a substance as a function of its pressure (y-axis) and temperature (x-axis).
- The regions in a phase diagram represent conditions under which a single stable state (solid, liquid, gas) exists.
- The lines in a phase diagram represent conditions under which two states are in equilibrium.
- The triple point represents the conditions under which all three states coexist.
- The critical point is the temperature and pressure above which a supercritical fluid exists.

The Uniqueness of Water (11.9)

- Water is a liquid at room temperature despite its low molar mass. Water forms strong hydrogen bonds and therefore has a high boiling point.
- The polarity of water enables it to dissolve many polar and ionic compounds and even nonpolar gases.
- Water expands upon freezing, so ice is less dense than liquid water.
- Water is critical both to the existence of life and to human health.

Key Equations and Relationships

Clausius–Clapeyron Equation: Relationship between Vapor Pressure (P_{vap}), the Heat of Vaporization (ΔH_{vap}), and Temperature (T) (11.5)

$$\begin{aligned} \ln P_{\text{vap}} &= \frac{-\Delta H_{\text{vap}}}{RT} + \ln \beta \qquad (\beta \text{ is a constant}) \\ \ln \frac{P_2}{P_2} &= \frac{-\Delta H_{\text{vap}}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \end{aligned}$$