

ANSWER KEY

Section Review 17.1

Part A Completion

- | | |
|-------------|-----------------|
| 1. polar | 7. high |
| 2. negative | 8. surface |
| 3. positive | 9. spherical |
| 4. polar | 10. surfactant |
| 5. hydrogen | 11. heat |
| 6. low | 12. temperature |

Part B True-False

- | | |
|--------|--------|
| 13. NT | 15. AT |
| 14. NT | 16. ST |

Part C Matching

- | | |
|-------|-------|
| 17. a | 19. d |
| 18. c | 20. b |

Part D Questions and Problems

- | | |
|--------------|-----------|
| 21. a. lower | d. higher |
| b. higher | e. higher |
| c. higher | |
22. $4.18 \text{ J/g}^\circ\text{C} \times 100.0 \text{ g} \times 2.0^\circ\text{C} = 836 \text{ J}$
 $= 8.4 \times 10^2 \text{ J}$
23. $0.447 \text{ J/g}^\circ\text{C} \times 100.0 \text{ g} \times 20.0^\circ\text{C} = 894 \text{ J}$

Section Review 17.2

Part A Completion

- | | |
|---------------------|----------------------|
| 1. hydrogen bonding | 7. exception |
| 2. energy | 8. hydrogen bonding |
| 3. molecules | 9. Ice |
| 4. condensation | 10. dense |
| 5. equal | 11. hydrogen bonding |
| 6. gases | |

Part B True-False

- | | |
|--------|--------|
| 12. NT | 14. AT |
| 13. ST | 15. ST |

Part C Questions and Problems

16. $86.0 \text{ g} \times 2.26 \text{ kJ/g} = 194 \text{ kJ}$

17. Water molecules are held strongly together by hydrogen bonds. Liquid methane has no hydrogen bonds. It takes much more heat to disrupt the attractions between water molecules than the attractions between methane molecules.

Section Review 17.3

Part A Completion

- | | |
|--------------------------|-------------------|
| 1. solvent | 6. partially |
| 2. homogeneous | 7. conduct |
| 3. "like dissolves like" | 8. nonelectrolyte |
| 4. electrolytes | 9. hydrates |
| 5. strong | 10. efflorescence |

Part B True-False

- | | |
|--------|--------|
| 11. AT | 13. ST |
| 12. AT | 14. AT |

Part C Matching

- | | | |
|-------|-------|-------|
| 15. d | 18. b | 21. c |
| 16. a | 19. f | 22. e |
| 17. h | 20. g | |

Part D Questions and Problems

23. Gram formula mass $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O} = 322 \text{ g}$
Mass of $10\text{H}_2\text{O} = 180.0 \text{ g}$
 $\frac{180.0 \text{ g}}{322 \text{ g}} \times 100\% = 55.9\%$
24. b and c

Section Review 17.4

Part A Completion

- | | |
|-------------------|-------------------|
| 1. larger | 6. molecules/ions |
| 2. filtration | 7. ions/molecules |
| 3. Colloids | 8. Emulsions |
| 4. Tyndall effect | 9. stability |
| 5. Brownian | 10. emulsions |

Part B True-False

- | | | |
|--------|--------|--------|
| 11. NT | 13. ST | 15. NT |
| 12. ST | 14. ST | |

Part C Matching

16. e 18. d 20. f
17. b 19. a 21. c

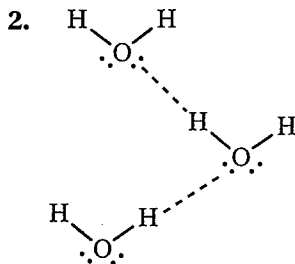
Part D Questions and Problems

22. b 23. a

Practice Problems 17

Section 17.1

1. Hydrogen bonds are attractive forces in which a hydrogen atom that is covalently bonded to a very electronegative atom is also weakly bonded to an unshared electron pair of an electronegative atom in the same molecule or in a nearby molecule.



3. Because hydrogen bonding prevents the escape of water molecules from the surface of the liquid, it takes more energy, and thus a higher temperature, for water molecules to gain sufficient kinetic energy to enter the vapor phase. Water begins to boil once the vapor pressure of the liquid is just equal to the external pressure on the liquid.
4. Because water has an exceptionally large heat capacity, it is able to transfer and absorb a great deal of heat. Large bodies of water are able to absorb heat from warm air masses, lowering the air temperature, and transfer heat to cold air masses, raising the air temperature.

5. $\Delta H = m \times C \times \Delta T$
 $\Delta H_{\text{water}} = (10.0 \text{ g}) \times [4.18 \text{ J}/(\text{g} \times ^\circ\text{C})] \times (30.0^\circ\text{C} - 20.0^\circ\text{C}) = 418 \text{ J}$
 $\Delta H_{\text{iron}} = (10.0 \text{ g}) \times [0.447 \text{ J}/(\text{g} \times ^\circ\text{C})] \times (30.0^\circ\text{C} - 20.0^\circ\text{C}) = 44.7 \text{ J}$
 $\frac{\Delta H_{\text{water}}}{\Delta H_{\text{iron}}} = \frac{418 \text{ J}}{44.7 \text{ J}} = 9.35$

For the same increase in temperature, water absorbs 9.35 times as much heat as does an equal mass of iron.

Section 17.2

1. As water vapor in the air condenses to liquid droplets, 2.26 kJ of heat is released per gram of vapor. This heat of condensation warms the surrounding air.
2. $180.0 \text{ g H}_2\text{O}(g) \times \frac{1 \text{ mol H}_2\text{O}(g)}{18.0 \text{ g H}_2\text{O}(g)} \times \frac{-40.7 \text{ kJ}}{1 \text{ mol H}_2\text{O}(g)}$
 $= 407 \text{ kJ}$
3. $78.3 \text{ g H}_2\text{O}(s) \times \frac{1 \text{ mol H}_2\text{O}(s)}{18.0 \text{ g H}_2\text{O}(s)} \times \frac{6.01 \text{ kJ}}{1 \text{ mol H}_2\text{O}(s)}$
 $= 26.1 \text{ kJ}$
4. Extensive hydrogen bonding in ice causes the water molecules to be held farther apart and in a more ordered arrangement than in liquid water. This open, honeycomb-like structure of ice results in a greater volume and, therefore, a lower density than liquid water at 0°C .

Section 17.3

1. The solute is potassium chloride (KCl). The solvent is water.
2. $\text{NH}_3(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$
3. Possible answers include glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) and ethyl alcohol ($\text{C}_2\text{H}_6\text{O}$).
4. Hygroscopic compounds are those compounds that remove moisture from air.
5. a. soluble c. soluble
b. insoluble d. soluble
6. a. $\text{NH}_4\text{NO}_3(s) \rightarrow \text{NH}_4^+(aq) + \text{NO}_3^-(aq)$
b. $\text{KOH}(s) \rightarrow \text{K}^+(aq) + \text{OH}^-(aq)$
7. a. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
b. $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$
8. Molar mass of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O} = 237.7 \text{ g/mol}$
Mass of $6\text{H}_2\text{O} = 108.0 \text{ g}$

$$\text{Percent H}_2\text{O} = \frac{\text{mass of water}}{\text{mass of hydrate}} \times 100\%$$
$$= \frac{108.0 \text{ g}}{237.7 \text{ g/mol}} \times 100\% = 45.44\%$$

Section 17.4

1. Colloids and suspensions exhibit the Tyndall effect and have larger particles than solutions. The particles in a suspension are retained on a filter and will settle out slowly upon standing.
2. Brownian motion refers to the chaotic movement of colloidal particles caused by the collisions of water molecules with the small, dispersed colloidal particles.

3. a. colloid e. suspension
 b. colloid f. colloid
 c. solution g. solution
 d. colloid

6. solute
 7. solvent
 8. aqueous solutions
 9. like dissolves like

$$10. 12 \text{ g water} \times \frac{2.26 \text{ kJ}}{1 \text{ g water}} = 27 \text{ kJ}$$

Interpreting Graphics 17

1. $10 \text{ cal/g} - 0 \text{ cal/g} = 10 \text{ cal/g}$
 $0 \text{ }^\circ\text{C} - (-20 \text{ }^\circ\text{C}) = 20 \text{ }^\circ\text{C}$
 $\frac{10 \text{ cal/g}}{20 \text{ }^\circ\text{C}} = 0.5 \text{ cal/(g } \times \text{ }^\circ\text{C)}$
2. $740 \text{ cal/g} - 730 \text{ cal/g} = 10 \text{ cal/g}$
 $120 \text{ }^\circ\text{C} - 100 \text{ }^\circ\text{C} = 20 \text{ }^\circ\text{C}$
 $\frac{10 \text{ cal/g}}{20 \text{ }^\circ\text{C}} = 0.5 \text{ cal/(g } \times \text{ }^\circ\text{C)}$
3. 740 cal
4. $1.00 \text{ g} \times (140 \text{ cal/g} - 10 \text{ cal/g}) = 130 \text{ cal}$
5. $90 \text{ cal/g} - 10 \text{ cal/g} = 80 \text{ cal/g}$
6. $1.00 \text{ g} \times (730 \text{ cal/g} - 140 \text{ cal/g}) = 590 \text{ cal}$
7. The melting and boiling points of water are $0 \text{ }^\circ\text{C}$ and $100 \text{ }^\circ\text{C}$ respectively. At these two temperatures, all of the heat energy absorbed by a sample of water is used to overcome the intermolecular forces holding molecules together in the solid and liquid states. Thus, even though heating continues at $0 \text{ }^\circ\text{C}$ and $100 \text{ }^\circ\text{C}$, the temperature remains constant until each phase change is complete.

Vocabulary Review 17

- desiccants
- hydrogen bonding
- heat of vaporization
- aqueous solution
- solvent
- surfactant
- strong electrolyte
- water of hydration
- Brownian motion

SOLUTION: 1. WATER VAPOR
 2. ICE
 3. LIQUID WATER

Quiz for Chapter 17

1. a 3. c 5. b
 2. a 4. c

Chapter 17 Test A

A. Completion

- nonelectrolyte
- deliquescent
- suspension
- solvent
- effloresce
- Brownian motion
- Emulsions
- hydrate
- Tyndall effect
- Surface tension

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. c | 16. a | 20. c |
| 12. d | 17. a | 21. a |
| 13. a | 18. a | 22. b |
| 14. b | 19. c | 23. c |
| 15. d | | |

C. True-False

- | | | |
|--------|--------|--------|
| 24. ST | 26. ST | 28. NT |
| 25. AT | 27. ST | |

D. Problems

29. Molar Mass of hydrate = 238 g
 $1 \text{ mol H}_2\text{O} = 18.0 \text{ g}$
 $6 \text{ mol H}_2\text{O} = 108 \text{ g}$

$$\frac{108 \text{ g}}{238 \text{ g}} \times 100\% = 45.4\%$$

$$30. 72 \text{ g steam} \times \frac{2.26 \text{ kJ}}{\text{g}} \times \frac{1000 \text{ J}}{1 \text{ kJ}} \times \frac{1 \text{ cal}}{4.18 \text{ J}}$$

$$= 3.9 \times 10^4 \text{ cal}$$

$$31. \Delta T = 48 \text{ }^\circ\text{C} - 15 \text{ }^\circ\text{C} = 33.0 \text{ }^\circ\text{C}$$

$$39.5 \text{ g H}_2\text{O} \times 4.18 \text{ J} \times \frac{1}{\text{g} \times \text{ }^\circ\text{C}} \times 33.0 \text{ }^\circ\text{C}$$

$$= 5.45 \times 10^3 \text{ J} = 5.45 \text{ kJ}$$

E. Essay

32. Because polar water molecules can attract charged particles, they cause solute ions to break away from the surface of the solid. As the solute dissolves, the ions are surrounded by molecules of solvent

Chapter 17 Test B

A. Completion

- | | |
|----------------|--------------------|
| 1. hygroscopic | 6. colloids |
| 2. solvation | 7. aqueous |
| 3. solute | 8. hydrogen |
| 4. surfactants | 9. nonelectrolytes |
| 5. desiccants | 10. effloresce |

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. b | 16. b | 21. c |
| 12. a | 17. c | 22. c |
| 13. b | 18. c | 23. d |
| 14. a | 19. d | 24. a |
| 15. d | 20. c | |

C. True-False

- | | | |
|--------|--------|--------|
| 25. AT | 29. AT | 32. NT |
| 26. NT | 30. AT | 33. AT |
| 27. AT | 31. AT | 34. AT |
| 28. ST | | |

D. Problems

35. $2.26 \frac{\text{kJ}}{\text{g}} \times 18.0 \frac{\text{g}}{\text{mol}} \times 0.25 \text{ mol} = 10.2 \text{ kJ}$
36. $2.26 \frac{\text{kJ}}{\text{g}} \times 12.0 \text{ g} \times 1000 \frac{\text{J}}{\text{kJ}} = 2.71 \times 10^4 \text{ J}$
37. $334 \frac{\text{J}}{\text{g}} \times \frac{1 \text{ kJ}}{1000 \text{ J}} \times 3.5 \text{ mol} \times \frac{18.0 \text{ g}}{\text{mol}} = 21 \text{ kJ}$
38. $\% \text{H}_2\text{O} = \frac{\text{mass of H}_2\text{O}}{\text{mass of hydrate}} \times 100\%$
 $= \frac{180.0 \text{ g}}{322.1 \text{ g}} \times 100\% = 55.9\%$

E. Essay

39. Soaps and detergents are surfactants that reduce the surface tension of water by interfering with the hydrogen bonding between water molecules. With the surface tension reduced, the beads of water that would normally have formed collapse, allowing the water to spread out to cover and

penetrate the fabric. Soaps and detergents also are emulsifying agents that allow oils and greases to form colloidal dispersions. The oil and grease particles, which are normally insoluble in water, are removed from the surface of the fabric.

Section Review 18.1

Part A Completion

- | | |
|------------------|--------------------|
| 1. particle size | 6. saturated |
| 2. rate | 7. miscible |
| 3. pressure | 8. solubility |
| 4. Henry's | 9. increases |
| 5. increasing | 10. supersaturated |

Part B True-False

- | | | |
|--------|--------|--------|
| 11. AT | 13. AT | 15. AT |
| 12. ST | 14. NT | |

Part C Matching

- | | | |
|-------|-------|-------|
| 16. c | 19. e | 21. b |
| 17. a | 20. g | 22. d |
| 18. f | | |

Part D Questions and Problems

23. $\frac{1.6 \text{ g/L}}{1.0 \text{ atm}} = \frac{S_2}{2.5 \text{ atm}}$
 $S_2 = \frac{1.6 \text{ g/L} \times 2.5 \text{ atm}}{1.0 \text{ atm}} = 4.0 \text{ g/L}$

Section Review 18.2

Part A Completion

- | | |
|-------------|-------------|
| 1. solvent | 5. liter |
| 2. solution | 6. diluting |
| 3. dilute | 7. solute |
| 4. moles | 8. solvent |

Part B True-False

- | | |
|--------|--------|
| 9. NT | 11. NT |
| 10. AT | 12. NT |

Part C Matching

- | | | |
|-------|-------|-------|
| 13. b | 15. e | 17. d |
| 14. c | 16. a | |

Part D Questions and Problems

18. $\text{gfm } \text{C}_{12}\text{H}_{22}\text{O}_{11} = 342.3$
 $M \times V = \text{mol solute needed}$
 $\frac{0.50 \text{ mol}}{1 \text{ L}} \times 0.3000 \text{ L} = 0.15 \text{ mol}$
 $\frac{342.3 \text{ g}}{1 \text{ mol}} \times 0.15 \text{ mol} = 51 \text{ g}$

Section Review 18.3

Part A Completion

- solute
- colligative properties
- freezing
- lowering/depression
- elevation
- directly
- solution
- particles
- twice
- twice

Part B True/False

11. NT 13. NT
12. ST 14. AT

Part C Matching

15. d 17. a
16. c 18. b

Part D Questions and Problems

19. a. two c. four
 b. one d. two
20. a. K_2CO_3 c. NaCl
 b. NaCl

Section Review 18.4

Part A Completion

- solute
- solvent
- 1000 g (kilogram)
- mole fraction
- molal boiling point
- depression
- molal
- elevation

Part B True-False

9. ST 11. AT
10. NT 12. AT

Part C Matching

13. b 15. a 17. c
14. e 16. d

Part D Questions and Problems

18. $\text{molality} = \frac{2.0 \text{ mol CaCl}_2}{800.0 \text{ g H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}}$
 $= 2.5m$
molality of total particles $= 3 \times 2.5m = 7.5m$
 $\Delta T_f = K_f \times m = \frac{1.86^\circ\text{C}}{m} \times 7.5m = 14^\circ\text{C}$
freezing point of solution $= 0^\circ\text{C} - 14^\circ\text{C}$
 $= -14^\circ\text{C}$

Practice Problems 18

Section 18.1

1. $S_2 = \frac{S_1 \times P_2}{P_1} = \frac{0.54 \text{ g/L} \times 1.86 \text{ atm}}{1.22 \text{ atm}}$
 $= 0.82 \text{ g/L}$
2. $\frac{34.0 \text{ g KCl}}{100 \text{ g H}_2\text{O}} \times 500.0 \text{ g H}_2\text{O} = 1.7 \times 10^2 \text{ g KCl}$
3. Solubility of AgNO_3 at 20°C
 $= 222.0 \text{ g}/100 \text{ g H}_2\text{O}$
Solubility of AgNO_3 at 50°C
 $= 455.0 \text{ g}/100 \text{ g H}_2\text{O}$
 $455.0 \text{ g} - 222.0 \text{ g} = 233.0 \text{ g}$
Add 233.0 g to maintain saturation at 50°C .

Section 18.2

1. a. $\frac{0.40 \text{ mol NaCl}}{1.6 \text{ L}} = 0.25M$
b. $\frac{20.2 \text{ g KNO}_3}{250.0 \text{ mL}} \times \frac{1 \text{ mol KNO}_3}{101.1 \text{ g KNO}_3} \times \frac{1000 \text{ mL}}{1 \text{ L}}$
 $= 0.799M$
2. a. $\text{moles KOH} = 2500.0 \text{ mL} \times \frac{1 \cancel{\text{L}}}{1000 \cancel{\text{mL}}}$
 $\times \frac{3.0 \text{ mol KOH}}{1 \cancel{\text{L}}} = 7.5 \text{ mol KOH}$
mass of KOH $= 7.5 \text{ mol KOH}$
 $\times \frac{56.1 \text{ g KOH}}{1 \text{ mol KOH}} = 4.2 \times 10^2 \text{ g KOH}$
b. $\text{moles HNO}_3 = 2.0 \cancel{\text{L}} \times \frac{2.0 \text{ mol HNO}_3}{\cancel{\text{L}}}$
 $= 4.0 \text{ mol HNO}_3$

$$\begin{aligned} \text{mass of HNO}_3 &= 4.0 \text{ mol HNO}_3 \\ &\times \frac{63 \text{ g HNO}_3}{1 \text{ mol HNO}_3} \\ &= 2.5 \times 10^2 \text{ g HNO}_3 \end{aligned}$$

$$3. \text{ moles NaNO}_3 = 212.5 \text{ g} \times \frac{1 \text{ mol}}{85.0 \text{ g}} = 2.50 \text{ mol}$$

$$\text{molarity} = \frac{2.50 \text{ mol}}{3.0 \text{ L}} = 0.83M$$

$$\begin{aligned} 4. M_1V_1 &= M_2V_2 \\ 0.750M \times 300.0 \text{ mL} &= 2.00M \times V_2 \\ \frac{0.750M \times 300.0 \text{ mL}}{2.00M} &= V_2 = 113 \text{ mL} \end{aligned}$$

$$5. V_2 = \frac{M_1 \times V_1}{M_2} = \frac{6.00M \times 1.0 \text{ L}}{0.500M} = 12 \text{ L}$$

The final volume should be 12 L. Therefore, add 11 L of H₂O.

$$\begin{aligned} 6. \text{ a. } \% \text{ (v/v)} &= \frac{60.0 \text{ mL methanol}}{500.0 \text{ mL solution}} \times 100\% \\ &= 12.0\% \text{ methanol (v/v)} \end{aligned}$$

$$\begin{aligned} \text{b. } \% \text{ (v/v)} &= \frac{25.0 \text{ mL C}_3\text{H}_7\text{OH}}{200.0 \text{ mL solution}} \times 100\% \\ &= 12.5\% \text{ C}_3\text{H}_7\text{OH (v/v)} \end{aligned}$$

$$7. \text{ a. } 1.00 \cancel{\text{ L}} \times \frac{10^3 \cancel{\text{ mL}}}{1 \cancel{\text{ L}}} \times \frac{3.00 \text{ g}}{100 \cancel{\text{ mL}}} = 30.0 \text{ g NaCl}$$

$$\begin{aligned} \text{b. } 2.00 \text{ L} \times \frac{10^3 \cancel{\text{ mL}}}{1 \cancel{\text{ L}}} \times \frac{5.00 \text{ g}}{100 \cancel{\text{ mL}}} &= \\ &= 1.00 \times 10^2 \text{ g KNO}_3 \end{aligned}$$

Section 18.3

- Colligative properties of solutions are the physical properties of solutions that depend on the concentration of solute particles in solution but not on the chemical identity of the solute. Three important colligative properties are vapor-pressure lowering, boiling-point elevation, and freezing-point depression.
- Each formula unit of K₂CO₃ produces three particles in solution.
- When 3 mol of Na₂SO₄ dissolve in water, there are 9 mol of particles because each formula unit of Na₂SO₄ dissociates into three ions.
- The boiling point of water increases by 0.512 °C for every mole of particles that the solute forms when dissolved in 1000 g of water. When 2 mol of MgCl₂ dissolve in water, 6 mol of particles are produced because each formula unit of MgCl₂ dissociates into three ions. Thus, the boiling point of the solution increases by 6 × 0.512 °C = 3.07 °C. The boiling point of the solution is

$$100 \text{ °C} + 3.07 \text{ °C} = 103.07 \text{ °C.}$$

- Vapor-pressure lowering is a colligative property.
- The solution containing calcium chloride has a lower freezing point.
 - The solution containing calcium chloride has a lower vapor pressure.
 - The solution containing sodium chloride has a lower boiling point.

Section 18.4

$$\begin{aligned} 1. \text{ a. } X_{\text{LiBr}} &= \frac{n_{\text{LiBr}}}{n_{\text{LiBr}} + n_{\text{H}_2\text{O}}} = \frac{3.0 \text{ mol}}{3.0 \text{ mol} + 6.0 \text{ mol}} \\ &= 0.33 \end{aligned}$$

$$\begin{aligned} \text{b. } X_{\text{KNO}_3} &= \frac{n_{\text{KNO}_3}}{n_{\text{KNO}_3} + n_{\text{H}_2\text{O}}} \\ &= \frac{(125 \text{ g} \times \frac{1 \text{ mol}}{101.1 \text{ g}})}{(125 \text{ g} \times \frac{1 \text{ mol}}{101.1 \text{ g}}) + (800.0 \text{ g} \times \frac{1 \text{ mol}}{18.0 \text{ g}})} \\ &= 0.0271 \end{aligned}$$

$$\begin{aligned} 2. 750.0 \text{ g H}_2\text{O} \times \frac{0.50 \text{ mol NaCl}}{1000 \text{ g H}_2\text{O}} \\ \times \frac{58.4 \text{ g NaCl}}{1 \text{ mol NaCl}} &= 22 \text{ g NaCl} \end{aligned}$$

$$\begin{aligned} 3. 1600.0 \text{ g H}_2\text{O} \times \frac{2.0 \text{ mol Li}_2\text{S}}{1000 \text{ g H}_2\text{O}} \\ \times \frac{45.9 \text{ g Li}_2\text{S}}{1 \text{ mol Li}_2\text{S}} &= 1.5 \times 10^2 \text{ g Li}_2\text{S} \end{aligned}$$

$$4. \text{ a. } \frac{2.3 \text{ mol glucose}}{500.0 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} = 4.6m \text{ glucose}$$

$$\begin{aligned} \text{b. moles Ba(NO}_3)_2 &= 131 \text{ g Ba(NO}_3)_2 \\ &\times \frac{1 \text{ mol Ba(NO}_3)_2}{261.3 \text{ g Ba(NO}_3)_2} \\ &= 0.501 \text{ mol Ba(NO}_3)_2 \end{aligned}$$

$$\begin{aligned} \frac{0.501 \text{ mol Ba(NO}_3)_2}{750.0 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \\ &= 0.668m \text{ Ba(NO}_3)_2 \end{aligned}$$

$$\begin{aligned} 5. \text{ a. } \Delta T_b &= K_b \times m \\ &= 0.512 \text{ °C/m} \times 2.00m \times 2 \\ &= 2.05 \text{ °C} \end{aligned}$$

The boiling point of this solution is 100 °C + 2.05 °C = 102.05 °C.

$$\begin{aligned} \text{b. } \Delta T_b &= K_b \times m \\ &= 0.512 \text{ °C/m} \times 1.50m \times 3 \\ &= 2.30 \text{ °C} \end{aligned}$$

The boiling point of this solution is 100 °C + 2.30 °C = 102.30 °C.

6. a. molality of solute particles

$$= 2 \times \frac{0.35 \text{ mol NaCl}}{900.0 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}}$$

$$= 0.78m \text{ NaCl}$$

$$\Delta T_f = K_f \times m$$

$$= 1.86 \text{ }^\circ\text{C}/m \times 0.78m$$

$$= 1.45 \text{ }^\circ\text{C}$$

The freezing point of this solution is

$$0 \text{ }^\circ\text{C} - 1.45 \text{ }^\circ\text{C} = -1.45 \text{ }^\circ\text{C}.$$

b. moles $\text{C}_{12}\text{H}_{22}\text{O}_{11} = 126.0 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}$

$$\times \frac{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{342.3 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}}$$

$$= 0.3681 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$$

molality of solute particles

$$= \frac{0.3681 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{2500.0 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}}$$

$$= 0.1472m \text{ C}_{12}\text{H}_{22}\text{O}_{11}$$

$$\Delta T_f = K_f \times m$$

$$= 1.86 \text{ }^\circ\text{C}/m \times 0.1472m$$

$$= 0.274 \text{ }^\circ\text{C}$$

The freezing point of this solution is

$$0 \text{ }^\circ\text{C} - 0.274 \text{ }^\circ\text{C} = -0.274 \text{ }^\circ\text{C}.$$

$$7. m = \frac{\Delta T_b}{K_b} = \frac{0.83 \text{ }^\circ\text{C}}{0.512 \text{ }^\circ\text{C}/m} = 1.6m$$

$$16.00 \text{ g H}_2\text{O} \times \frac{1 \text{ kg H}_2\text{O}}{10^3 \text{ g H}_2\text{O}} \times \frac{1.6 \text{ mol solute}}{1 \text{ kg H}_2\text{O}}$$

$$= 0.026 \text{ mol solute}$$

$$\text{molar mass} = \frac{4.69 \text{ g}}{0.026 \text{ mol}} = 180.4 \text{ g/mol}$$

Interpreting Graphics 18

1. b, c

2. Solubility KCl at 20 °C = 34.0 g/100 g H₂O

Solubility KCl at 50 °C = 42.6 g/100 g H₂O

$$= 42.6 \text{ g} - 34.0 \text{ g} = 8.6 \text{ g}$$

3. Solubility of sucrose at 100 °C

$$= 487 \text{ g/100 g H}_2\text{O}$$

Solubility of sucrose at 20 °C

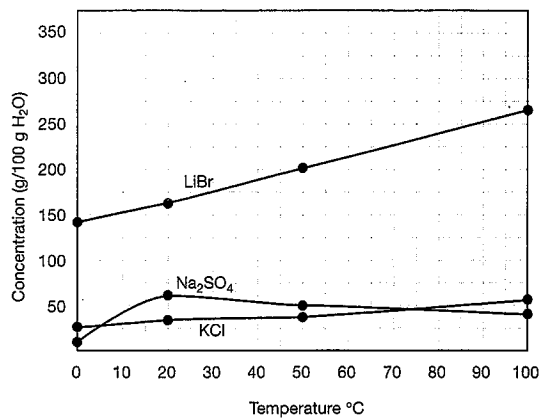
$$= 230.9 \text{ g/100 g H}_2\text{O}$$

$$(487 \text{ g/100 g H}_2\text{O} \times 1000.0 \text{ g H}_2\text{O})$$

$$- (230.9 \text{ g/100 g H}_2\text{O} \times 1000.0 \text{ g H}_2\text{O})$$

$$= 4870 \text{ g} - 2309 \text{ g} = 2561 \text{ g}$$

4.



a. LiBr

b. Na₂SO₄

Vocabulary Review 18

- Molarity. All others are qualitative terms used to describe solutions.
- Concentration. The other two terms are used to describe mixtures of two liquids.
- Henry's Law. All others are units of concentration.
- Colligative properties. All others are associated with the solubility of gases.
- Saturated solution. All others are associated with colligative properties of solutions.
- Molarity. All others are related to freezing-point depression
- Mole fraction. All others are factors affecting the rate at which a substance dissolves.
- Boiling-point elevation. All others are associated with the preparation of solutions.

Quiz for Chapter 18

- | | | |
|------|------|------|
| 1. b | 4. a | 7. c |
| 2. d | 5. b | 8. b |
| 3. a | 6. c | |

Chapter 18 Test A

A. Matching

- | | | |
|------|------|-------|
| 1. b | 5. f | 8. a |
| 2. i | 6. d | 9. h |
| 3. g | 7. j | 10. e |
| 4. c | | |

B. Multiple Choice

11. c 15. c 19. a
12. d 16. b 20. b
13. a 17. a 21. d
14. c 18. b

C. True-False

22. ST 26. NT 29. AT
23. AT 27. NT 30. ST
24. AT 28. NT 31. NT
25. AT

D. Problems

32. $V_2 = 250 \text{ mL}$, $M_2 = 0.60M$, $M_1 = 2.0M$
 $M_1 V_1 = M_2 V_2$
 $0.60M \times 250 \text{ mL} = 2.0M \times V_1$
 $V_1 = \frac{0.60M \times 250 \text{ mL}}{2.0M} = 75 \text{ mL}$
Add 75 mL of 2.0M $\text{Al}_2(\text{SO}_4)_3$ to enough distilled water to make 250 mL of solution.

33. gfm KNO_3 :
K: $1 \times 39.1 = 39.1 \text{ g}$
N: $1 \times 14.0 = 14.0 \text{ g}$
O: $3 \times 16.0 = 48.0 \text{ g}$
 101.1 g
 $\text{mol KNO}_3 = \frac{95.5 \text{ g}}{101.1 \text{ g/mol}} = 0.945 \text{ mol}$
 $\text{molarity} = \frac{0.945 \text{ mol}}{0.750 \text{ L}} = 1.26M$

34. $\frac{S_1}{P_1} = \frac{S_2}{P_2}$
 $S_2 = \frac{S_1 \times P_2}{P_1} = \frac{16.9 \text{ g/L} \times 606 \text{ kPa}}{505 \text{ kPa}}$
 $= 20.3 \text{ g/L}$

E. Essay

35. Boiling-point elevation, and freezing-point and vapor-pressure lowering are colligative properties. They depend solely on the number of particles in the solution.

Boiling-point elevation: Additional attractive forces exist between solute and solvent that must be overcome for the solution to boil.

Freezing-point depression: The solute particles interfere with the formation of the orderly pattern that the solvent particles assume as the solvent changes from liquid to solid.

Vapor-pressure lowering: The formation of solvent shells around the solute particles reduces the number of solvent particles that have sufficient kinetic energy to vaporize.

F. Additional Problems

36. $\frac{\text{mol K}_3\text{PO}_4}{1000 \text{ g H}_2\text{O}}$
 $= \frac{0.900 \text{ mol K}_3\text{PO}_4}{2750 \text{ g H}_2\text{O}} \times \frac{1000 \text{ g H}_2\text{O}}{1 \text{ kg H}_2\text{O}}$
 $= 0.327m$
 $\text{K}_3\text{PO}_4 \rightarrow 3\text{K}^+ + \text{PO}_4^{3-} = 4 \text{ particles}$
 $4 \text{ particles} \times 0.327m = 1.31m$
 $\Delta T_b = K_b m$
 $= 0.512 \frac{^\circ\text{C}}{m} \times 1.31m$
 $= 0.671 \text{ }^\circ\text{C}$
The boiling point of the solution is $100.671 \text{ }^\circ\text{C}$.
37. gfm KNO_3 :
K: $1 \times 39.1 = 39.1 \text{ g}$
N: $1 \times 14.0 = 14.0 \text{ g}$
O: $3 \times 16.0 = 48.0 \text{ g}$
 101.1 g
 $\frac{\text{mass KNO}_3}{\text{gfm}} = \frac{175 \text{ g}}{101.1 \text{ g/mol}} = 1.73 \text{ mol}$
 $\text{molality} = \frac{\text{mol solute}}{1000 \text{ g solvent}}$
 $= \frac{1.73 \text{ mol KNO}_3}{1250 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g H}_2\text{O}}{1 \text{ kg H}_2\text{O}}$
 $= 1.38m$
38. $m = \frac{\Delta T_f}{K_f} = \frac{-3.26 \text{ }^\circ\text{C}}{-1.86 \text{ }^\circ\text{C}/m} = 1.75m$
 $55.0 \text{ g H}_2\text{O} \times \frac{1 \text{ kg H}_2\text{O}}{10^3 \text{ g H}_2\text{O}} \times \frac{1.75 \text{ mol solute}}{1 \text{ kg H}_2\text{O}}$
 $= 0.0963 \text{ mol solute}$
 $\text{molar mass} = \frac{10.6 \text{ g}}{0.0963 \text{ mol}} = 110 \text{ g/mol}$

Chapter 18 Test B

A. Matching

1. g 5. d 8. i
2. c 6. a 9. j
3. h 7. f 10. b
4. e

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. d | 17. a | 22. a |
| 12. a | 18. b | 23. c |
| 13. b | 19. d | 24. a |
| 14. b | 20. b | 25. b |
| 15. c | 21. d | 26. a |
| 16. a | | |

C. True-False

- | | | |
|--------|--------|--------|
| 27. AT | 31. ST | 34. AT |
| 28. NT | 32. NT | 35. NT |
| 29. NT | 33. NT | 36. AT |
| 30. NT | | |

D. Problems

$$37. \frac{100.0 \text{ g H}_2\text{O}}{216 \text{ g AgNO}_3} \times (725 \text{ g AgNO}_3) = 336 \text{ g H}_2\text{O}$$

$$38. \frac{S_1}{P_1} = \frac{S_2}{P_2}$$
$$P_2 = \frac{S_2 \times P_1}{S_1}$$
$$P_2 = \frac{6.25 \text{ g/L} \times 0.750 \text{ atm}}{2.45 \text{ g/L}}$$
$$P_2 = 1.91 \text{ atm}$$

$$39. \frac{50.0 \text{ g Mg(NO}_3)_2}{225 \text{ mL}} \times 1000 \frac{\text{mL}}{\text{L}}$$
$$\times \frac{1 \text{ mol Mg(NO}_3)_2}{148.3 \text{ g Mg(NO}_3)_2} = 1.50 \text{ M}$$

$$40. \frac{0.250 \text{ mol AgNO}_3}{1 \text{ kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times 125 \text{ g}$$
$$\times \frac{169.9 \text{ g AgNO}_3}{1 \text{ mol AgNO}_3} = 5.31 \text{ g AgNO}_3$$

41. Salt is often used on bridges and sidewalks because it dissolves in an ice/ice water mixture to produce a solution with a lower freezing point than that of water alone. This causes any ice that was initially present to melt, and prevents additional ice from forming down to temperatures below 0 °C. The salt causes the freezing point of water to be depressed because it interferes with the crystallization process.

F. Additional Problems

$$42. \frac{0.15 \text{ mol H}_2\text{SO}_4}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 750 \text{ mL}$$
$$\times \frac{98.1 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 11 \text{ g H}_2\text{SO}_4$$

$$43. \Delta T_f = K_f \times m$$
$$= 1.86 \text{ }^\circ\text{C/m} \times \frac{27.5 \text{ g CH}_3\text{OH}}{250.0 \text{ g}}$$
$$\times \frac{1 \text{ mol CH}_3\text{OH}}{32.0 \text{ g CH}_3\text{OH}} \times \frac{1000 \text{ g}}{1 \text{ kg}}$$
$$= 6.39 \text{ }^\circ\text{C}$$

$$\text{freezing point} = 0 \text{ }^\circ\text{C} - 6.39 \text{ }^\circ\text{C} = -6.39 \text{ }^\circ\text{C}$$

44. molality of total particles

$$= \frac{62.5 \text{ g Ba(NO}_3)_2}{750.0 \text{ g}} \times \frac{1 \text{ mol Ba(NO}_3)_2}{261 \text{ g Ba(NO}_3)_2}$$
$$\times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{3 \text{ moles particles}}{1 \text{ mol Ba(NO}_3)_2}$$
$$= 0.958 \text{ m}$$

$$\Delta T_b = K_b \times m = 0.512 \text{ }^\circ\text{C/m} \times 0.958 \text{ m}$$
$$= 0.490 \text{ }^\circ\text{C}$$

$$\text{boiling point} = 100 \text{ }^\circ\text{C} + 0.490 \text{ }^\circ\text{C}$$
$$= 100.490 \text{ }^\circ\text{C}$$

45. $\Delta T_f = K_f \times m$

$$m = \frac{\Delta T_f}{K_f} = \frac{0.570 \text{ }^\circ\text{C}}{1.79 \text{ }^\circ\text{C/m}}$$
$$= 0.318 \text{ m or } \frac{0.318 \text{ mol}}{1 \text{ kg}}$$
$$\frac{0.318 \text{ mol}}{1 \text{ kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times 1110 \text{ g} = 0.353 \text{ mol}$$
$$\frac{31.8 \text{ g}}{0.353 \text{ mol}} = 90.1 \text{ g/mol}$$

Section Review 19.1

Part A Completion

- | | |
|-------------------|----------------|
| 1. Rates | 6. products |
| 2. react | 7. slower |
| 3. kinetic energy | 8. temperature |
| 4. activation | 9. catalyst |
| 5. minimum | 10. increasing |

Part B True-False

- | | |
|--------|--------|
| 11. ST | 13. AT |
| 12. NT | 14. AT |

Part C Matching

- | | | |
|-------|-------|-------|
| 15. b | 17. f | 19. e |
| 16. d | 18. a | 20. c |

Part D Questions and Problems

21. 120 kg/24 hr = 5.0 kg/hr
22. b, d

Section Review 19.2

Part A Completion

1. reversible
2. products
3. forward
4. reactants
5. reverse
6. reactants
7. products
8. equilibrium
9. equilibrium constant
10. ratio
11. Le Châtelier's

Part B True-False

12. NT
13. ST
14. NT
15. AT

Part C Matching

16. e
17. a
18. c
19. d
20. f
21. b

Part D Questions and Problems

$$22. K_{\text{eq}} = \frac{[\text{SO}_2]^2 [\text{O}_2]}{[\text{SO}_3]^2}$$
$$= \frac{(0.42M)^2 (0.21M)}{(0.072M)^2} = 7.145M = 7.1M$$

Section Review 19.3

Part A Completion

1. spontaneous
2. nonspontaneous
3. energy
4. work
5. free energy
6. energy
7. greater
8. entropy
9. disorder
10. law of disorder
11. maximum

Part B True-False

12. ST
13. AT
14. AT
15. AT
16. ST

Part C Matching

17. b
18. e
19. d
20. a
21. c

Part D Questions and Problems

22. a. a heap of loose stamps
b. ice cubes in a bucket
c. 10 mL of steam at 100 °C
d. the people watching the parade
23. b
24. d

Section 19.4

Part A Completion

1. entropy
2. standard entropy
3. reactants
4. products
5. Gibbs free-energy change
6. enthalpy
7. formation
8. reactants
9. products

Part B True-False

10. AT
11. ST
12. NT
13. AT

Part C Matching

14. d
15. b
16. a
17. c

Part D Questions and Problems

$$18. S^\circ \text{Fe}(s) = 27.2 \text{ J/(K} \cdot \text{mol)}$$
$$S^\circ \text{O}_2(g) = 205.0 \text{ J/(K} \cdot \text{mol)}$$
$$S^\circ \text{Fe}_2\text{O}_3 = 90.0 \text{ J/(K} \cdot \text{mol)}$$
$$\Delta S^\circ = S^\circ(\text{products}) - S^\circ(\text{reactants})$$
$$= 2 \text{ mol Fe}_2\text{O}_3 \times \frac{90.0 \text{ J/(K} \cdot \text{mol)}}{\text{mol Fe}_2\text{O}_3}$$
$$- \left[4 \text{ mol Fe} \times \frac{27.2 \text{ J/(K} \cdot \text{mol)}}{\text{mol Fe}} \right]$$
$$+ 3 \text{ mol O}_2 \times \frac{205.0 \text{ J/(K} \cdot \text{mol)}}{\text{mol O}_2} \left. \vphantom{2 \text{ mol Fe}_2\text{O}_3} \right]$$
$$= 180 \text{ J/(K} \cdot \text{mol)}$$
$$- [108.8 \text{ J/(K} \cdot \text{mol)} + 615.0 \text{ J/(K} \cdot \text{mol)}]$$
$$= -543.8 \text{ J/(K} \cdot \text{mol)} = -544 \text{ J/(K} \cdot \text{mol)}$$

19. $\Delta G^0 = \Delta H^0 - T\Delta S^0$
 $= -163 \text{ kJ/mol} - [298\text{K} \times -0.51 \text{ kJ}/(\text{K}\cdot\text{mol})]$
 $= -163 \text{ kJ/mol} + 152 \text{ kJ/mol}$
 $= -11 \text{ kJ/mol}$
 The reaction is spontaneous.

Section 19.5

Part A Completion

- rate
- concentration
- rate law
- specific rate constant
- order
- first-order
- second order
- experiment
- elementary reaction
- mechanism

Part B True-False

11. NT 13. AT
 12. ST 14. AT

Part C Matching

15. d 17. b 19. e
 16. f 18. a 20. c

Part D Questions and Problems

21. This diagram represents a reaction that takes place in two elementary steps. Both steps are exothermic. Points *A* and *C* represent the energy level of the activated complexes. Point *B* represents the energy level of the intermediate product. Point *D* represents the energy level of the final product.

Practice Problems 19

Section 19.1

- Rates of chemical reactions can usually be increased by (1) increasing the temperature, (2) increasing the concentration of the reactants, (3) decreasing the reactant particle size, and (4) using of a catalyst.
- 2 mol/4 hrs = 0.5 mol/hr
- a. decrease the rate
b. increase the rate
- increase the rate

Section 19.2

- $K_{\text{eq}} = \frac{[\text{NO}_2]^4 \times [\text{O}_2]}{[\text{N}_2\text{O}_5]^2}$
- $K_{\text{eq}} = \frac{[0.80 \text{ mol/L}]^4 \times [0.20 \text{ mol/L}]}{[0.50 \text{ mol/L}]^2}$
 $= 0.33 \text{ (mol/L)}^3$
- a. shift left
b. shift right
- $5.6 = \frac{0.66}{x^2}$
 $x^2 = 0.12$
 $x = 0.34 \text{ mol/L}$
- a. $K_{\text{eq}} = \frac{[\text{N}_2\text{O}_4]^2}{[\text{NO}]^4 \times [\text{O}_2]^2}$
 b. $K_{\text{eq}} = \frac{[\text{NOBr}]^2}{[\text{NO}]^2 \times [\text{Br}_2]}$
 c. $K_{\text{eq}} = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}] \times [\text{H}_2]^2}$
 d. $K_{\text{eq}} = \frac{[\text{SO}_3] \times [\text{NO}]}{[\text{SO}_2] \times [\text{NO}_2]}$
- a. shift right
b. shift right
c. shift right
d. no shift
- $K_{\text{eq}} = 1 \times 10^{12}$
- $K_{\text{eq}} = \frac{[\text{H}_2]^2 \times [\text{S}_2]}{[\text{H}_2\text{S}]^2}$
 $K_{\text{eq}} = \frac{[0.014]^2 \times [0.035]}{[0.18]^2} = 2.1 \times 10^{-4}$

Section 19.3

- increase in entropy
- decrease in entropy
- a. increasing c. increasing
b. increasing
- a. D c. D
b. N d. A

Section 19.4

- $\Delta S^0 = S^0 \text{ (products)} - S^0 \text{ (reactants)}$
 $= [2(69.94 \text{ J/K}) + 205.0 \text{ J/K}] - 2(92 \text{ J/K})$
 $= 139.88 \text{ J/K} + 205.0 \text{ J/K} - 184 \text{ J/K}$
 $= 160.88 \text{ J/K} = 161 \text{ J/K}$
- $[4(186.7 \text{ J/K}) + 205.0 \text{ J/K}]$
 $- [2(188.7 \text{ J/K}) + 2(233.0 \text{ J/K})] = 108.4 \text{ J/K}$
- $117 \text{ J/K} - 260.6 \text{ J/K} = -144 \text{ J/K}$
- $2(213.6 \text{ J/K}) - [2(197.9 \text{ J/K}) + 205.0 \text{ J/K}]$
 $= -173.6 \text{ J/K}$

5. High temperatures. This would make the value of $T\Delta S$ larger and, thus, increase the probability for a negative ΔG .
6. $\Delta G = \Delta H - T\Delta S$
 $= -78 \text{ kJ/mol}$
 $\quad - [558 \text{ K} \times (-0.122 \text{ kJ/K} \times \text{mol})]$
 $= -10 \text{ kJ/mol}$

Reaction is spontaneous. Since ΔG is negative at 285 °C.

7. $\Delta G^0 = [3 \text{ mol} (-394.4 \text{ kJ/mol}) + 0 \text{ kJ/mol}]$
 $\quad - [2 \text{ mol} (-741.0 \text{ kJ/mol}) + 0 \text{ kJ/mol}]$
 $= -1183.2 \text{ kJ} - [-1482 \text{ kJ}]$
 $= 298.8 \text{ kJ}$
8. a. $\Delta G^0 = [4 \text{ mol} (86.69 \text{ kJ/mol})$
 $\quad + 6 \text{ mol} (-237.2 \text{ kJ/mol})]$
 $\quad - [4 \text{ mol} (-16.64 \text{ kJ/mol})$
 $\quad + 5 \text{ mol} (0.0 \text{ kJ/mol})]$
 $= [346.8 - 1423] - [-66.56]$
 $= -1.010 \times 10^3 \text{ kJ}$, spontaneous
- b. $\Delta G^0 = [2 \text{ mol} (-370.4 \text{ kJ/mol})]$
 $\quad - [2 \text{ mol} (-300.4 \text{ kJ/mol}) + 0.0 \text{ kJ}]$
 $= [-740.8] - [-600.8]$
 $= -140.0 \text{ kJ}$, spontaneous
- c. $\Delta G^0 = (-228.6 \text{ kJ} - 50.79 \text{ kJ})$
 $\quad - [3 \text{ mol} (0.0 \text{ kJ/mol}) + (-137.3 \text{ kJ})]$
 $= -142.1 \text{ kJ}$, spontaneous.

Section 19.5

1. $2.4 \text{ mol}/(\text{L} \times \text{s}) \div 8 = 0.30 \text{ mol}/(\text{L} \times \text{s})$
2. $\text{rate} = k[\text{HgCl}_2][\text{Na}_2\text{C}_2\text{O}_4]^2$
3. $\text{rate} = k[\text{J}][\text{K}]$
 The reaction is first order in both J and K.
4. $\text{rate} = k[\text{H}_2\text{O}_2]$; $k = \text{rate}/[\text{H}_2\text{O}_2]$
 $k = 0.00842 \text{ mol}/(\text{L} \times \text{s}) \div 0.500 \text{ mol/L}$
 $= 0.0168 \text{ s}^{-1}$
5. There are three elementary reactions.
6. 1.0; 0.020
7. a. There are two elementary reactions.
 b. $\text{C}_3\text{H}_8\text{O}_3$
 c. $\text{rate} = k[\text{C}_2\text{H}_4\text{O}_2][\text{CH}_4\text{O}]$

Interpreting Graphics 19

- | | |
|----------------|-------------|
| 1. a. negative | d. positive |
| b. negative | e. positive |
| c. negative | f. positive |
| 2. a. negative | d. positive |
| b. positive | e. negative |
| c. negative | f. positive |

3. greater
 4. less
 5. Example A
 6. yes

Vocabulary Review 19

- | | | |
|------|------|-------|
| 1. e | 5. b | 8. d |
| 2. g | 6. f | 9. c |
| 3. i | 7. j | 10. h |
| 4. a | | |

Quiz for Chapter 19

- | | | |
|------|-------|--------|
| 1. b | 5. d | 8. AT |
| 2. d | 6. d | 9. AT |
| 3. a | 7. NT | 10. NT |
| 4. b | | |

Chapter 19 Test A

A. Matching

- | | | |
|------|------|-------|
| 1. i | 5. g | 8. d |
| 2. a | 6. e | 9. f |
| 3. j | 7. h | 10. b |
| 4. c | | |

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. b | 16. c | 20. a |
| 12. b | 17. d | 21. b |
| 13. b | 18. b | 22. a |
| 14. d | 19. c | 23. d |
| 15. d | | |

C. Problems

$$24. K_{\text{eq}} = \frac{[\text{NO}]^2 \times [\text{Cl}_2]}{[\text{NOCl}]^2} = \frac{(1.2)^2 (0.60)}{(0.30)^2} = 9.6$$

$$25. 2.2 \times 10^2 \text{ L}^2/\text{mol}^2 = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}] \times [\text{H}_2]^2}$$

$$2.2 \times 10^2 \text{ L}^2/\text{mol}^2 = \frac{[\text{CH}_3\text{OH}]}{(0.020 \text{ mol/L})(0.60 \text{ mol/L})^2}$$

$$= \frac{[\text{CH}_3\text{OH}]}{0.0072 \text{ mol}^3/\text{L}^3}$$

$$\frac{2.2 \times 10^2 \text{ L}^2}{\text{mol}^2} \times 0.0072 \frac{\text{mol}^3}{\text{L}^3} = [\text{CH}_3\text{OH}]$$

$$1.58 \text{ mol/L} = [\text{CH}_3\text{OH}]$$

26. a. favors products
 b. favors reactants
 c. favors products
 d. favors reactants

D. Essay

27. Spontaneous reactions are reactions that, under the conditions specified, are known to favor formation of products.

Nonspontaneous reactions do not favor formation of products under the specified conditions. Some spontaneous reactions appear to be nonspontaneous because their rate is so slow.

E. Additional Problems

28. Doubling A doubles the rate—first order in A. Doubling B increases the rate 8 times ($2^3 = 8$)—third order in B. First order + third order = fourth order overall.

29. $273\text{ }^\circ\text{C} + 25^\circ = 298\text{ K}$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= 53 \frac{\text{kJ}}{\text{mol}} - 298 \text{ K} \times \frac{(0.070 \text{ kJ})}{\text{K} \cdot \text{mol}}$$

$$= 53 \frac{\text{kJ}}{\text{mol}} - 21 \frac{\text{kJ}}{\text{mol}}$$

$$= 32 \frac{\text{kJ}}{\text{mol}}$$

This reaction is not spontaneous, because G° is positive.

30. $\Delta S^\circ = S^\circ(\text{products}) - S^\circ(\text{reactants})$
 $= 2 \frac{\text{mol H}_2\text{O}_2 \times 92.0 \text{ J}/(\text{K} \cdot \text{mol})}{\text{mol H}_2\text{O}_2}$
 $- \left[2 \frac{\text{mol H}_2\text{O} \times 69.92 \text{ J}/(\text{K} \cdot \text{mol})}{\text{mol H}_2\text{O}} \right.$
 $\left. + 1 \frac{\text{mol O}_2 \times 205.0 \text{ J}/(\text{K} \cdot \text{mol})}{\text{mol O}_2} \right]$
 $= -161 \text{ J}/(\text{K} \cdot \text{mol})$

Chapter 19 Test B

A. Matching

- | | | |
|------|------|-------|
| 1. j | 5. f | 8. e |
| 2. g | 6. c | 9. b |
| 3. h | 7. d | 10. a |
| 4. i | | |

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. d | 16. c | 21. c |
| 12. a | 17. d | 22. b |
| 13. d | 18. b | 23. c |
| 14. b | 19. d | 24. b |
| 15. c | 20. a | |

C. Problems

25. a. shifts left; decreases
 b. shifts left; decreases
 c. shifts right; increases
 d. shifts right; increases
 e. shifts right; increases
 f. shifts left; decreases

$$26. K_{\text{eq}} = \frac{[\text{H}_2\text{O}]^2[\text{Cl}_2]^2}{[\text{HCl}]^4[\text{O}_2]}$$

$$= \frac{[5.8 \times 10^{-2}]^2[5.8 \times 10^{-2}]^2}{[1.2 \times 10^{-3}]^4[3.8 \times 10^{-4}]}$$

$$1.4 \times 10^{10}$$

27. $\Delta S^\circ = S^\circ(\text{products}) - S^\circ(\text{reactants})$
 $= [4(240.5 \text{ J}/\text{K} \times \text{mol}) + 6(188.7 \text{ J}/\text{K} \times \text{mol})]$
 $- [4(192.5 \text{ J}/\text{K} \times \text{mol}) + 7(205.0 \text{ J}/\text{K} \times \text{mol})]$
 $= [2094 \text{ J}/(\text{K} \times \text{mol})] - [2205 \text{ J}/(\text{K} \times \text{mol})]$
 $= -111 \text{ J}/(\text{K} \times \text{mol})$

D. Essay

28. a. The addition of more reactant causes an increase in the rate of the forward reaction, which consumes that reactant.
 b. An increase in temperature causes the endothermic reaction to speed up in an effort to consume the additional heat.
 c. An increase in pressure (for a gaseous system with an unequal number of molecules) causes the reaction that produces the fewest number of molecules to speed up.

E. Additional Problems

$$29. K_{\text{eq}} = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$$

$$[\text{N}_2] = \frac{[\text{NH}_3]^2}{K_{\text{eq}}[\text{H}_2]^3}$$

$$= \frac{[1.23 \times 10^{-4}]^2}{(6.59 \times 10^{-3})[2.75 \times 10^{-6}]^3}$$

$$= 1.10 \times 10^{11} \text{ mol/L}$$

$$30. \Delta G^{\circ} = \Delta G_f^{\circ}(\text{products}) - \Delta G_f^{\circ}(\text{reactants})$$

$$= [(-394.4 \text{ kJ/mol}) + 2(-237.2 \text{ kJ/mol})]$$

$$- [(-50.79 \text{ kJ/mol}) + 2(0.00 \text{ kJ/mol})]$$

$$= [-868.8 \text{ kJ/mol}] - [-50.79 \text{ kJ/mol}]$$

$$= -818.0 \text{ kJ/mol}$$

$$31. \Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

$$= (-85.2 \text{ kJ/mol})$$

$$- (400 \text{ K})(0.125 \text{ kJ/K} \times \text{mol})$$

$$= -135.2 \text{ kJ/mol}$$

The reaction is spontaneous.

Section Review 20.1

Part A Completion

- | | |
|-------------|----------------|
| 1. acids | 6. hydrogen |
| 2. metals | 7. hydrobromic |
| 3. hydrogen | 8. nitric |
| 4. Bases | 9. hydroxide |
| 5. water | 10. bases |

Part B True-False

11. ST 12. NT 13. NT

Part C Matching

14. a 16. d
15. c 17. b

Part D Questions and Problems

18. a. $\text{Mg}(\text{OH})_2$ c. H_3PO_4
b. HF d. LiOH
19. a. potassium hydroxide
b. hydroiodic acid
c. sulfuric acid
d. ethanoic acid (acetic acid)

Section 20.2

Part A Completion

- self-ionize
- 1×10^{-7}
- 0 to 14
- hydrogen ion
- acidic
- basic
- neutral
- 7
- ion-product

10. hydronium/hydroxide

11. hydroxide/hydronium

Part B True-False

12. AT 14. AT 16. NT
13. AT 15. NT

Part C Matching

17. c 20. a 22. g
18. f 21. b 23. d
19. e

Part D Questions and Problems

24. $K_w = [\text{H}^+][\text{OH}^-]$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{1 \times 10^{-14}}{1 \times 10^{-10}} = 1 \times 10^{-4}$$

The solution is basic.

25. a. $\text{pH} = -\log[\text{H}^+]$
 $[\text{H}^+] = 1 \times 10^{-3} \text{ M}$
- b. $\text{pH} = -\log[\text{H}^+]$
 $[\text{H}^+] = 1 \times 10^{-6} \text{ M}$
- c. $\text{pH} = -\log[\text{H}^+]$
 $[\text{H}^+] = 1 \times 10^{-10} \text{ M}$

Section 20.3

Part A Completion

- three
- Arrhenius
- hydroxide ions
- proton
- acceptor
- electron-pair
- donor
- monoprotic
- diprotic
- conjugate acid-base pair
- amphoteric

Part B True-False

12. NT 14. AT 16. AT
13. NT 15. ST

Part C Matching

17. g 20. h 23. c
18. d 21. e 24. f
19. a 22. i 25. b

Part D Questions and Problems

26. Dimethyl ether is a Lewis base because it donates an electron pair to form a bond. Boron trifluoride is a Lewis acid because it accepts an electron pair from dimethyl ether.

Section 20.4

Part A Completion

1. degree of ionization
2. K_a
3. larger
4. pH
5. completely
6. strong
7. weak
8. bases
9. water
10. acid
11. strong

Part B True-False

12. ST 14. AT
13. NT 15. ST

Part C Matching

16. c 18. a 20. d
17. e 19. b 21. f

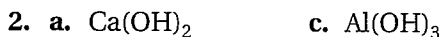
Part D Questions and Problems

22. $\text{HX} \rightleftharpoons \text{H}^+ + \text{X}^-$
 $[\text{H}^+] = [\text{X}^-] = 4.1 \times 10^{-2}$
 $[\text{HX}] = 0.35 - 4.1 \times 10^{-2} = 0.35 - 0.041$
 $= 0.309$
 $K_a = \frac{[\text{H}^+][\text{X}^-]}{[\text{HX}]} = \frac{(4.1 \times 10^{-2})(4.1 \times 10^{-2})}{0.309}$
 $= 5.4 \times 10^{-3}$

Practice Problems

Section 20.1

1. a. anion name: nitrite
acid name: nitrous acid
- b. anion name: sulfate
acid name: sulfuric acid
- c. anion name: fluoride
acid name: hydrofluoric acid
- d. anion name: carbonate
acid name: carbonic acid



3. Acids have a tart or sour taste and cause indicators to change color. Acids react with compounds containing hydroxide ions to produce a salt and water.
4. Aqueous solutions of bases taste bitter and feel slippery. They react with acids to produce a salt and water. Bases cause indicators to change color.

Section 20.2

1. $\text{pH} = -\log[\text{H}^+]$
 $= -\log(1 \times 10^{-6})$
reminder: the $\log(a \times b) = \log a + \log b$
 $= -(0.0 + (-6))$
reminder: the $\log 1 = 0.0$
 $= 6.0$

2. $\text{pH} = -\log[\text{H}^+]$
 $= -\log(7.2 \times 10^{-9})$
 $= -(0.86) - (-9.00)$
Use log tables or your calculator to find the log of 7.2.
 $= 9.00 - 0.86$
 $= 8.14$

3. $\text{pOH} = -\log[\text{OH}^-]$
 $= -\log(3.5 \times 10^{-2})$
 $= -(0.54) - (-2.00)$
 $= 2.00 - 0.54$
 $= 1.46$

4. $\text{pOH} = 14.0 - \text{pH}$
 $= 14.0 - 3.4$
 $= 10.6$

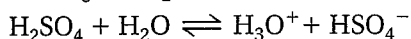
5. a. basic d. neutral
b. acidic e. acidic
c. acidic

6. a. 5.0 c. 7.34
b. 10.36 d. 12.6
7. a. acidic c. basic
b. basic d. basic

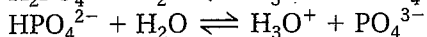
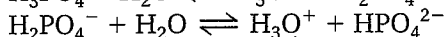
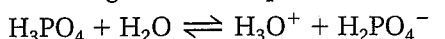
8. Most acidic solutions of interest have a hydrogen ion concentration of less than 1M. The log of this concentration would always be a negative number. Taking the negative log (minus sign in the pH definition) ensures that the pH values will usually be positive.
9. $\text{pH} + \text{pOH} = 14.0$
 $\text{pH} = 14.0 - \text{pOH} = 14.0 - 12.4 = 1.6$
10. $\text{pH} = -\log[\text{H}^+]$
 $= -\log(1 \times 10^{-3}) = -(0.0 + (-3)) = 3.0$

Section 20.3

1. H_2SO_4 and H_3O^+ are proton donors and H_2O and HSO_4^- are the proton acceptors. The conjugate acid–base pairs are $\text{H}_2\text{SO}_4/\text{HSO}_4^-$ and $\text{H}_3\text{O}^+/\text{H}_2\text{O}$.



2. H_3PO_4 is a triprotic acid able to ionize three hydrogens. All ions formed are shown in the following chemical equations.



3. Only hydrogens bonded to highly electronegative atoms are ionizable.

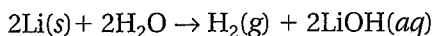
a. monoprotic

b. monoprotic

c. diprotic

d. triprotic

4. Like other alkali metals, lithium reacts violently with water to produce hydrogen and the base lithium hydroxide.



5. BF_3 can accept a pair of electrons to form a covalent bond and is therefore a Lewis acid. Since F^- donates the pair of electrons, it is a Lewis base.

Section 20.4

1. strong base, weak base, weak acid, strong acid

2. $\text{HF}(aq) \rightleftharpoons \text{H}^+(aq) + \text{F}^-(aq)$

$$K_a = \frac{[\text{H}^+][\text{F}^-]}{[\text{HF}]}$$

3. $\text{N}_2\text{H}_4(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{N}_2\text{H}_5^+(aq) + \text{OH}^-(aq)$

$$K_b = \frac{[\text{N}_2\text{H}_5^+][\text{OH}^-]}{[\text{N}_2\text{H}_4]}$$

4. The weakest acid has the smallest K_a .
 $\text{HCO}_3^- < \text{H}_2\text{PO}_4^- < \text{HCOOH} < \text{H}_2\text{C}_2\text{O}_4$

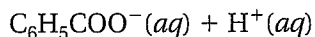
5. a. $\text{H}_2\text{S}(aq) \rightleftharpoons \text{H}^+(aq) + \text{HS}^-(aq)$

$$K_a = \frac{[\text{H}^+][\text{HS}^-]}{[\text{H}_2\text{S}]}$$

- b. $\text{NH}_4^+(aq) \rightleftharpoons \text{NH}_3(aq) + \text{H}^+(aq)$

$$K_a = \frac{[\text{NH}_3][\text{H}^+]}{[\text{NH}_4^+]}$$

- c. $\text{C}_6\text{H}_5\text{COOH}(aq) \rightleftharpoons$



$$K_a = \frac{[\text{C}_6\text{H}_5\text{COO}^-][\text{H}^+]}{[\text{C}_6\text{H}_5\text{COOH}]}$$

6. a. (4) d. (5)

- b. (2) e. (3)

- c. (1)

$$7. K_b = \frac{[\text{C}_6\text{H}_5\text{NH}_3^+][\text{OH}^-]}{[\text{C}_6\text{H}_5\text{NH}_2]}$$

$$8. K_a = \frac{(4.2 \times 10^{-3}M)(4.2 \times 10^{-3}M)}{0.096M}$$

$$= 1.8 \times 10^{-4}M$$

9. At equilibrium, $[\text{H}^+] = x = [\text{C}_6\text{H}_5\text{COO}^-]$

$$[\text{C}_6\text{H}_5\text{COOH}] = 0.20M - x = 0.20M$$

(since $x \ll 0.20M$)

$$K_a = \frac{x^2}{0.20M} = 6.3 \times 10^{-5}M$$

$$x = 3.5 \times 10^{-3}M = [\text{H}^+]$$

10. At equilibrium, $[\text{H}^+] = [\text{CN}^-] = 6.3 \times 10^{-6}M$

$$K_a = \frac{[\text{H}^+][\text{CN}^-]}{[\text{HCN}]}$$

$$= \frac{(6.3 \times 10^{-6}M)^2}{0.10M} = 4.0 \times 10^{-10}M$$

Interpreting Graphics 20

1. methyl red

2. phenolphthalein

3. a

4. b

5. c

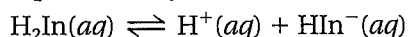
6. a

7. b

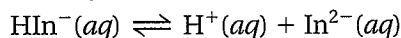
8. $\text{HIn}(aq) \rightleftharpoons \text{H}^+(aq) + \text{In}^-(aq)$

9. The greater the acid strength of the indicator the lower the pH range at which it changes color. phenolphthalein < bromthymol blue < methyl red

10. Thymol blue is a diprotic acid and undergoes a color change at each ionization step. If H_2In represents thymol blue, then:



red to yellow



yellow to blue

Vocabulary Review 20

1. Basic solution. The other three terms all are interrelated. The ion-product constant of water is always equal to the product of the hydrogen ion and hydroxide ion concentration in any aqueous solution.

- Hydronium ion. The other terms describe aqueous solutions based on their pH.
- Acidic solution. Alkaline is another name for a basic solution and basic solutions would have a high hydroxide ion concentration.
- Dissociation constant. The other terms are all related to the hydrogen ion concentration or pH of a solution.
- Amphoteric. The other terms are theories used to classify acids and bases.
- Lewis acid. The other terms refer to ways of describing acids and bases according to the Brønsted-Lowry theory.
- Amphoteric. The other terms are used to describe acids based on the number of ionizable hydrogens.
- Strong acids. Weak acids and bases are only partially ionized in aqueous solution. The dissociation constant reflects the fraction of a weak base or weak acid that is in ionized form.

Quiz for Chapter 20

- | | | |
|------|------|------|
| 1. b | 4. c | 6. d |
| 2. b | 5. c | 7. b |
| 3. a | | |

Chapter 20 Test A

A. Matching

- | | | |
|------|------|-------|
| 1. i | 5. h | 8. e |
| 2. a | 6. g | 9. c |
| 3. j | 7. d | 10. b |
| 4. f | | |

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. b | 17. c | 23. c |
| 12. d | 18. d | 24. a |
| 13. d | 19. a | 25. a |
| 14. a | 20. b | 26. d |
| 15. c | 21. d | 27. a |
| 16. d | 22. d | 28. c |

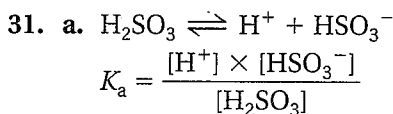
C. Problems

- $\text{pH} = -\log[\text{H}^+] = 9$, basic
- $[\text{H}^+] = 1 \times 10^{-4}$, $\text{pH} = 4$, acidic
- $[\text{H}^+] = 1 \times 10^{-13}$, $\text{pH} = 13$, basic
- $\text{pH} = 7$, neutral

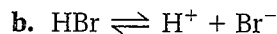
$$30. K_w = [\text{H}^+] \times [\text{OH}^-]$$

$$[\text{H}^+] = \frac{K_w}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{1 \times 10^{-12}}$$

$$= 1 \times 10^{-2} \text{ acidic}$$

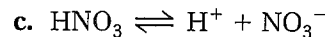


sulfurous acid



$$K_a = \frac{[\text{H}^+] \times [\text{Br}^-]}{[\text{HBr}]}$$

hydrobromic acid



$$K_a = \frac{[\text{H}^+] \times [\text{NO}_3^-]}{[\text{HNO}_3]}$$

nitric acid

D. Essay

- Both acids and bases are electrolytes, cause indicators to change colors, and react with each other to form water and a salt. Acids taste sour; bases taste bitter. Bases feel slippery. Acids react with some metals to produce hydrogen gas.

Chapter 20 Test B

A. Matching

- | | | |
|------|------|-------|
| 1. b | 5. f | 8. j |
| 2. g | 6. c | 9. i |
| 3. d | 7. h | 10. e |
| 4. a | | |

B. Multiple Choice

- | | | |
|-------|-------|-------|
| 11. b | 16. b | 21. c |
| 12. c | 17. d | 22. a |
| 13. a | 18. a | 23. b |
| 14. b | 19. d | 24. a |
| 15. c | 20. a | |

C. Problems

- $K_w = [\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14} \text{ (mol/L)}^2$
 $[\text{OH}^-] = K_w / [\text{H}^+]$
 $[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ (mol/L)}^2}{1.0 \times 10^{-9} \text{ mol/L}}$
 $= 1.0 \times 10^{-5} \text{ mol/L}$
 The solution is basic.

26. a. $[\text{OH}^-] = 1 \times 10^{-11}$; 3; acidic
 b. $[\text{H}^+] = 1 \times 10^{-6}$; 6; acidic
 c. $[\text{OH}^-] = 1 \times 10^{-2}$; 12; basic
 d. $[\text{H}^+] = 1 \times 10^{-7}$; 7; neutral
27. a. $K_a = \frac{[\text{H}^+][\text{I}^-]}{[\text{HI}]}$
 b. $K_a = \frac{[\text{H}^+][\text{HSO}_4^-]}{[\text{H}_2\text{SO}_4]}$
 c. $K_a = \frac{[\text{H}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$

D. Essay

28. The Brønsted-Lowry theory defines acids as proton donors and bases as proton acceptors. According to the Lewis theory, acids are electron-pair acceptors, whereas bases are electron-pair donors.

E. Additional Problems

29. $\text{pH} = -\log [\text{H}^+]$
 $= -\log [3.4 \times 10^{-4}]$
 $= -(\log 3.4 + \log 10^{-4})$
 $= -[(0.53) + (-4)]$
 $= -[-3.47]$
 $= 3.47$
- The solution is acidic.
30. a. $\text{HF}(aq)$; $\text{H}_2\text{O}(l)$; $\text{H}_3\text{O}^+(aq)$; $\text{F}^-(aq)$
 b. $\text{HCl}(g)$; $\text{H}_2\text{O}(l)$; $\text{H}_3\text{O}^+(aq)$; $\text{Cl}^-(aq)$
 c. $\text{HC}_2\text{H}_3\text{O}_2(aq)$; $\text{H}_2\text{O}(l)$; $\text{H}_3\text{O}^+(aq)$; $\text{C}_2\text{H}_3\text{O}_2^-(aq)$
31. a. H^+ ; I^-
 b. BCl_3 ; NH_3
32. $\text{HC}_2\text{H}_3\text{O}_2(aq) \rightleftharpoons \text{H}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$
 $[\text{H}^+] = [\text{C}_2\text{H}_3\text{O}_2^-] = 2.25 \times 10^{-3}M$
 $[\text{HC}_2\text{H}_3\text{O}_2] = 0.1000M - 0.00225M$
 $= 0.09775M$
- $$K_a = \frac{[\text{H}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$$
- $$= \frac{[0.00225][0.00225]}{[0.09775]}$$
- $$= 5.18 \times 10^{-5}$$