18 SOLUTIONS
PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
18.1 Properties of Solutions **Objectives** ▸ Identify the factors that determine the rate at which a solute dissolves ▸ Calculate the solubility of a gas in a liquid under various pressure conditions	**Discover It!** *Salt and the Freezing Point of Water*, p. 500 **Link to Agriculture** *Fertilizer Runoff*, 502 **Sample Problem** 18-1 **Mini Lab** *Solutions and Colloids*, p. 508	**Review Module** (Chapters 17–20) ▸ Section Review 18.1 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheet** 18-1 **Laboratory Manual** ▸ Experiment 30: *Factors Affecting Solution Formation* ▸ Experiment 31: *Supersaturation* **Laboratory Practical** 18-1 **Small-Scale Chemistry Lab Manual,** Experiment 23: *Solubility Rules*
18.2 Concentrations of Solutions **Objectives** ▸ Solve problems involving the molarity of a solution ▸ Describe how to prepare dilute solutions from more-concentrated solutions of known molarity ▸ Explain what is meant by percent by volume (% (v/v)) and percent by mass (% (m/v)) solutions	**Link to Nursing** *Intravenous Solutions*, p. 510 **Sample Problems** 18-2 through 18-6 **Small-Scale Lab** *Making a Solution*, p. 516	**Review Module** ▸ Section Review 18.2 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheet** 18-2 **Laboratory Manual,** Experiment 32: *Chromatography*
18.3 Colligative Properties of Solutions **Objectives** ▸ Explain on a particle basis why a solution has a lower vapor pressure than the pure solvent of that solution ▸ Explain on a particle basis why a solution has an elevated boiling point and a depressed freezing point compared to the pure solvent		**Review Module** ▸ Section Review 18.3 ▸ Practice Problems ▸ Quizzes **Laboratory Manual,** Experiment 33: *Freezing Point*
18.4 Calculations Involving Colligative Properties **Objectives** ▸ Calculate the molality and mole fraction of a solution ▸ Calculate the molar mass of a molecular compound from the freezing-point depression or boiling-point elevation of a solution of the compound	**Sample Problems** 18-7 through 18-10 **Chemistry Serving . . . Society** *A Solution for Kidney Failure*, p. 526 **Chemistry in Careers** *Nephrology Nurse*, p. 526	**Review Module** ▸ Section Review 18.4 ▸ Practice Problems ▸ Vocabulary Review 18 ▸ Chapter 18 Tests and Quizzes **Laboratory Manual,** Experiment 33: *Freezing Point* **Solutions Manual for Chapter Reviews** **Graphing Calculator Problems**

TECHNOLOGY RESOURCES

Internet Connections
Within this chapter, you will see the chemSURF logo. If you and your students have access to the Internet, the following URL address will provide various Internet connections that are related to topics and features presented in this chapter.

http://www.chemsurf.com

You can also find relevant chapter material at
The Chemistry Place address:
http://www.chemplace.com

CD-ROMs

Chem ASAP! CD-ROM
- Chapter 18

ResourcePro CD-ROM
- Chapter 18

ActivChemistry CD-ROM
- Properties of Solutions

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Big Bottle Shake
- Molarity

Overhead Transparencies
- #60: Dynamic Equilibrium
- #61: Solubility and Temperature
- #62: Concentrated and Dilute Solutions

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 500
- plastic plates
- string or narrow ribbon
- water
- ice cubes
- table salt

Mini Lab p. 508
- sodium hydrogen carbonate
- cornstarch
- distilled water (or tap water)
- flashlights
- black construction paper
- masking tape
- jars with parallel sides
- teaspoons
- cups

Small-Scale Lab, p. 516
- solid NaCl
- water
- 50-mL plastic volumetric bottles
- balances

TEACHER'S EDITION

Teacher Demo, p. 505
- bottle of warm soda
- bottle of cold soda
- 2 other bottles of soda

Activity, p. 511
- 500 mL of water
- volumetric flask
- NaCl
- 0.0625*M*, 0.125*M*, 0.250*M*, and 0.500*M* solutions of sucrose
- 100-mL and 50-mL volumetric flasks

Teacher Demo, p. 514
- four 20-mL test tubes
- 10 mL of 0.5*M* sucrose for one test tube
- 5 mL water for each of the other test tubes
- 10-mL pipet

Activity, p. 519
- ice water
- rock salt
- thermometer
- Styrofoam cup

Activity, p. 524
- different concentrations of an NaCl or ethylene glycol solution
- thermometers

ASSESSMENT

Student Edition
- Section Reviews 18.1–18.4
- Chapter 18 Review, pp. 527–530
- Alternative Assessment, p. 531

Technology
Chem ASAP! CD-ROM
- Assessment 18.1–18.4

Assessment Resources CD-ROM
- Chapter 18 Tests

Teacher's Resource Package
Review Module (Chap. 17–20)
- Vocabulary Review
- Chapter 18 Test A and Test B
- Chapter 18 Quizzes

Name _____ Class _____ Date _____

18.1 PROPERTIES OF SOLUTIONS
SECTION REVIEW

Objectives

- Identify the factors that determine the rate at which a solute dissolves
- Calculate the solubility of a gas in a liquid under various pressure conditions

Key Terms

- saturated solution
- solubility
- unsaturated
- miscible
- immiscible
- Henry's law
- supersaturated solution

Key Equation

- Henry's law: $\frac{S_1}{P_1} = \frac{S_2}{P_2}$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

Changes in the temperature of a system and __1__ of a solute alter the __2__ at which a solute dissolves. The extent to which a gas dissolves in a liquid is proportional to the __3__ of the gas in accordance with __4__ law. The solubility of a gas decreases with __5__ temperature. A solution that contains the maximum amount of solute at a given temperature is said to be __6__. Two liquids that are mutually soluble in each other are said to be __7__. Generally the __8__ of a solid in water __9__ with increasing temperature, but there are exceptions. A __10__ solution holds more solute than theoretically possible.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** The rate at which a solute dissolves can be increased by grinding.

_____ **12.** As the temperature of a solvent decreases, the solubility of a solute increases.

_____ **13.** Stirring a solute when adding it to a solvent should increase the rate of its dissolving.

_____ **14.** Henry's law states that the solubility of a gas in a liquid is a function of temperature.

_____ **15.** Two liquids which dissolve in each other are miscible.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **16.** saturated solution	**a.** the amount of a substance that dissolves in a given quantity of solvent at a given temperature
_____ **17.** solubility	**b.** The solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.
_____ **18.** unsaturated	**c.** solution that contains the maximum amount of solute for a given amount of solvent at a constant temperature
_____ **19.** miscible	**d.** a solution containing more solute than it can theoretically hold at a given temperature
_____ **20.** immiscible	**e.** description of two liquids that dissolve in each other
_____ **21.** Henry's law	**f.** a solution that contains less solute than possible at a given temperature
_____ **22.** supersaturated solution	**g.** description of two liquids that do not dissolve in each other

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

23. The solubility of a gas in water is 1.6 g/L at 1.0 atm of pressure. What is the solubility of the same gas at 2.5 atm? Assume the temperature to be constant.

Name _____ Class _____ Date _____

18.2 CONCENTRATIONS OF SOLUTIONS
SECTION REVIEW

Objectives

- Solve problems involving the molarity of a solution
- Describe how to prepare dilute solutions from more concentrated solutions of known molarity
- Explain what is meant by percent by volume [%(v/v)] and percent by mass [%(m/v)] solutions

Key Terms

- concentration
- dilute solution
- concentrated solution
- molarity (M)

Key Equations

- Molarity (M) $= \dfrac{\text{moles of solute}}{\text{liters of solution}}$
- $M_1 \times V_1 = M_2 \times V_2$
- Percent by volume [%(v/v)] $= \dfrac{\text{volume of solute}}{\text{solution volume}} \times 100\%$
- Percent (mass/volume)[%(m/v)] $= \dfrac{\text{mass of solute (g)}}{\text{solution volume (mL)}} \times 100\%$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

The relative amounts of solute and __1__ in a __2__ can be described qualitatively as __3__ or concentrated. Quantitative units of concentration include molar concentration, percent by volume, and percent (mass/volume).

Molarity, the most important unit of concentration in chemistry, is expressed as __4__ of solute per __5__ of solution.

Solutions of different concentrations can be prepared by __6__ a stock solution. In dilution, the moles of __7__ remain the same, while the amount of __8__ changes.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **9.** One hundred mL of 1.0*M* sodium hydroxide solution is more concentrated than 1.0 L of 5*M* sodium hydroxide solution.

_____ **10.** The amount of sodium hydroxide in 100 mL of 1.0*M* NaOH is less than that in 1.0 L of 5*M* NaOH solution.

_____ **11.** Fifty mL of a 32% solution (v/v) of ethyl alcohol in water would contain 42 mL of water.

_____ **12.** A dilute solution is a quantitative expression of concentration.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **13.** concentration	**a.** number of moles of solute dissolved in 1 L of solution
_____ **14.** dilute solution	**b.** measure of the amount of solute that is dissolved in a given quantity of solvent
_____ **15.** concentrated solution	**c.** solution that contains a low concentration of solute
_____ **16.** molarity	**d.** concentration expressed as volume or mass of solute over volume of solution × 100%
_____ **17.** percent solution	**e.** solution that contains a high concentration of solute

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

18. What mass of sucrose, $C_{12}H_{22}O_{11}$, is needed to make 300.0 mL of a 0.50*M* solution?

Name _____ Class _____ Date _____

18.3 COLLIGATIVE PROPERTIES OF SOLUTIONS
SECTION REVIEW

Objectives

- Explain on a particle basis why a solution has a lower vapor pressure than the pure solvent of that solution
- Explain on a particle basis why a solution has an elevated boiling point and a depressed freezing point compared with the pure solvent

Key Terms

- colligative properties
- boiling-point elevation
- freezing-point depression

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

The effects in solution of a nonvolatile __1__ on the properties of the solvent are called __2__. They include __3__ point and vapor pressure __4__, and boiling point __5__. In each case, the magnitude of the effect is __6__ proportional to the number of solute molecules or ions present in the __7__.

Colligative properties are a function of the number of solute __8__ in solution. For example, one mole of sodium chloride produces __9__ as many particles in solution as one mole of sucrose and, thus, will depress the freezing point of water __10__ as much.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** When added to 1000 g of water, 2 moles of a solute will increase the boiling point by 0.512 °C.

_____ **12.** One mole of solute A will depress the freezing point of 1000 g of water the same as one mole of solute B.

_____ **13.** Addition of a nonvolatile solute will lower the boiling point of a solvent.

_____ **14.** Addition of a nonvolatile solute will lower the freezing point of a solvent.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** colligative properties	**a.** difference between the freezing point of a solution and the freezing point of the pure solvent
_____ **16.** boiling-point elevation	**b.** pressure exerted by a vapor that is in equilibrium with its liquid in a closed system
_____ **17.** freezing-point depression	**c.** difference between the boiling point of a solution and the boiling point of the pure solvent
_____ **18.** vapor pressure	**d.** properties of solutions that depend only on the number of particles in solution

Part D Questions and Problems

Answer the following questions in the space provided.

19. How many moles of solute particles are produced by adding one mole of each of the following to water?

a. sodium nitrate

b. glucose

c. aluminum chloride

d. potassium iodide

20. An equal number of moles of NaCl and K_2CO_3 are dissolved in equal volumes of water. Which solution has the higher

a. boiling point?

b. vapor pressure?

c. freezing point?

Name _____ Class _____ Date _____

18.4 CALCULATIONS INVOLVING COLLIGATIVE PROPERTIES
SECTION REVIEW

Objectives

- Calculate the molality and mole fraction of a solution
- Calculate the molar mass of a molecular compound from the freezing-point depression or boiling-point elevation of a solution of the compound

Key Terms

- molality (m)
- mole fraction
- molal boiling-point elevation constant (K_b)
- molal freezing-point depression constant (K_f)

Key Equations

- $\text{Molality} = \dfrac{\text{moles of solute}}{\text{kilogram of solvent}} = \dfrac{\text{moles of solute}}{1000\text{ g of solvent}}$
- mole fractions: $X_A = \dfrac{n_A}{n_A + n_B}$ $X_B = \dfrac{n_B}{n_A + n_B}$

  where n_A = moles of solute
  n_B = moles of solvent
- $\Delta T_b = K_b \times m$
- $\Delta T_f = K_f \times m$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

Molality is an expression of concentration involving the ratio of __1__ particles to __2__ particles. Molality is expressed as moles of solute per __3__ of solvent.

Another expression of concentration is __4__, in which concentrations are expressed as the ratio of moles of solute to the total number of moles of solvent and solute. Each solvent has a characteristic __5__ elevation constant and molal freezing-point __6__ constant. The elevation in boiling point of a solution can be calculated by multiplying the __7__ concentration of the solution by the boiling-point __8__ constant of the solvent.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **9.** It is possible to calculate the molar mass of a solute if you know the K_b or K_f of a solvent.

_____ **10.** Molal concentration is the same as molar concentration.

_____ **11.** The depression in freezing point of a solution is proportional to the molal concentration of solute.

_____ **12.** The sum of X_A and X_B for any solution is always 1.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **13.** molality	**a.** a constant for a given solvent equal to the change in boiling point for a 1*m* solution
_____ **14.** mole fraction	**b.** number of moles of solute dissolved in 1 kilogram of solvent
_____ **15.** molal boiling-point elevation constant	**c.** mass of one mole of a substance
_____ **16.** molal freezing-point depression constant	**d.** a constant for a given solvent equal to the change in freezing point for a 1*m* solution
_____ **17.** molar mass	**e.** ratio of moles of solute in solution to the total number of moles of solute and solvent

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

18. What is the freezing point of a solution that contains 2.0 mol of $CaCl_2$ in 800.0 g of water? K_f for water = 1.86 °C/*m*

Name _____ Class _____ Date _____

18 SOLUTIONS
PRACTICE PROBLEMS

Read each question or statement and respond in your notebook.

SECTION 18.1 PROPERTIES OF SOLUTIONS

1. The solubility of CO_2 in water at 1.22 atm is 0.54 g/L. What is the solubility of carbon dioxide at 1.86 atm? Assume that temperature is constant.
2. What mass of KCl will produce a saturated solution in 500.0 g of water at 20 °C?
3. A saturated solution of silver nitrate is prepared in 100.0 g of water at 20 °C. The solution is then heated to 50.0 °C. How much more silver nitrate must now be added to obtain a saturated solution?

SECTION 18.2 CONCENTRATIONS OF SOLUTIONS

1. Calculate the molarity of each of the following solutions.
   a. 0.40 mol of NaCl dissolved in 1.6 L of solution
   b. 20.2 g of potassium nitrate, KNO_3, in enough water to make 250.0 mL of solution
2. Calculate the number of grams of solute needed to prepare each of the following solutions.
   a. 2500.0 mL of a 3.0*M* solution of potassium hydroxide, KOH
   b. 2.0 liters of 2.0*M* nitric acid, HNO_3, solution
3. What is the molarity of a solution that contains 212.5 g of sodium nitrate ($NaNO_3$) in 3.0 liters of solution?
4. You must prepare 300.0 mL of 0.750*M* NaBr solution using 2.00*M* NaBr stock solution. How many milliliters of stock solution should you use?
5. In order to dilute 1.0 L of a 6.00*M* solution of NaOH to 0.500*M* solution, how much water must you add?
6. What is the concentration in percent by volume, %(v/v), of the following solutions?
   a. 60.0 mL of methanol in a total volume of 500.0 mL
   b. 25.0 mL of rubbing alcohol (C_3H_7OH) diluted to a volume of 200.0 mL with water
7. How many grams of solute are needed to prepare each of the following solutions?
   a. 1.00 L of a 3.00% (m/v) NaCl solution?
   b. 2.00 L of 5.00% (m/v) KNO_3 solution?

Name _____ Class _____ Date _____

SECTION 18.3 COLLIGATIVE PROPERTIES OF SOLUTIONS

1. What are colligative properties of solutions? Give examples of three types of colligative properites.
2. How many particles in solution are produced by each formula unit of potassium carbonate, K_2CO_3?
3. How may moles of particles would 3 mol Na_2SO_4 give in solution?
4. What is the boiling point of a solution that contains 2 mol of magnesium chloride in 100.0 g of water?
5. What kind of property is vapor-pressure lowering?
6. An equal number of moles of NaCl and $CaCl_2$ are dissolved in equal volumes of water. Which solution has the lower
   a. freezing point?
   b. vapor pressure?
   c. boiling point?

SECTION 18.4 CALCULATIONS INVOLVING COLLIGATIVE PROPERTIES

1. Calculate the mole fraction of solute in each of the following solutions.
   a. 3.0 moles of lithium bromide, LiBr, dissolved in 6.0 moles of water
   b. 125.0 g of potassium nitrate, KNO_3, dissolved in 800.0 g of water
2. How many grams of sodium chloride must dissolve in 750.0 g of water to make a 0.50 molal solution?
3. How many grams of lithium sulfide must be dissolved in 1600.0 g of water to make a 2.0 molal solution?
4. Find the molality of each of the following solutions.
   a. 2.3 moles of glucose dissolved in 500.0 g of water
   b. 131 g of $Ba(NO_3)_2$ dissolved in 750.0 g of water
5. Find the boiling points of the following solutions.
   a. 2.00*m* solution of sodium chloride, NaCl
   b. 1.50*m* solution of calcium chloride, $CaCl_2$
6. Find the freezing points of the following solutions.
   a. 0.35 moles of sodium chloride, NaCl, dissolved in 900.0 g of water
   b. 126.0 g of table sugar, $C_{12}H_{22}O_{11}$, dissolved in 2500.0 g of water
7. A solution of 4.69 g of a nonvolatile compound in 16.00 g of water boils at 100.83 °C at 760 mm Hg. What is the molar mass of the solute? Assume that the solute exists as molecules not ions.

Name _____ Class _____ Date _____

18 INTERPRETING GRAPHICS

USE WITH SECTION 18.1

Solubilities of Some Substances in Water at Various Temperatures					
		Solubility (g/100 g of H_2O)			
Substance	**Formula**	**0 °C**	**20 °C**	**50 °C**	**100 °C**
Barium hydroxide	$Ba(OH)_2$	1.67	31.89	—	—
Barium sulfate	$BaSO_4$	0.00019	0.00025	0.00034	—
Calcium hydroxide	$Ca(OH)_2$	0.189	0.173	—	0.07
Lead(II) chloride	$PbCl_2$	0.60	0.99	1.70	—
Lithium carbonate	Li_2CO_3	1.5	1.3	1.1	0.70
Potassium chlorate	$KClO_3$	4.0	7.4	19.3	56.0
Potassium chloride	KCl	27.6	34.0	42.6	57.6
Sodium chloride	NaCl	35.7	36.0	37.0	39.2
Sodium nitrate	$NaNO_3$	74	88.0	114.0	182
Sodium sulfate	Na_2SO_4	4.76	62	50.0	41.0
Silver nitrate	$AgNO_3$	122	222.0	455.0	733
Lithium bromide	LiBr	143.0	166	203	266.0
Cane sugar (sucrose)	$C_{12}H_{22}O_{11}$	179	230.9	260.4	487

A portion of Table 18.1 from your textbook has been reproduced above. Use the table to answer the following questions.

1. Saturated solutions of each of the following compounds are made at 20 °C. Circle the letter(s) of the solution(s) which will form a precipitate upon heating.

   a. NaCl

   b. Na_2SO_4

   c. Li_2CO_3

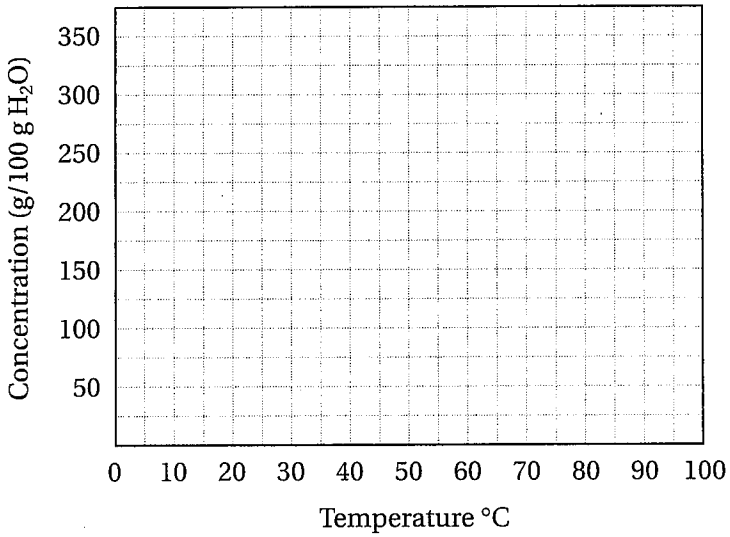
   d. sucrose

2. A saturated solution of potassium chloride is prepared in 100.0 g of water at 20 °C. If the solution is heated to 50 °C, how much more KCl must be added to obtain a saturated solution?

Name _____ Class _____ Date _____

3. A saturated solution of sucrose in 1000.0 g of boiling water is cooled to 20 °C. What mass of rock candy will be formed?

4. Using data from the table, plot the solubility curves of KCl, LiBr and Na_2SO_4 on the graph below. Be sure to label each curve. Use the graph to answer the following questions.



a. Which of the compounds is most soluble at 25 °C?

_____

_____

b. Which of the compounds has the lowest solubility at 90 °C?

_____

_____

Name _____ Class _____ Date _____

18 VOCABULARY REVIEW

From each group of terms, choose the term that does not belong and then explain your choice.

1. saturated, unsaturated, molarity, supersaturated

2. miscible, immiscible, concentration

3. molarity, mole fraction, molality, Henry's law

4. solubility of a gas, Henry's law, pressure, colligative properties

5. colligative properties, saturated solution, freezing-point depression, molality

6. molal freezing-point depression constant (K_f), colligative properties, ice cream, molarity

7. surface area, mole fraction, temperature, stirring

8. dilute solution, concentrated solution, $M_1 \times V_1 = M_2 \times V_2$, boiling-point elevation

Name _____ Class _____ Date _____

18 SOLUTIONS

Quiz for CHAPTER 18

Write the letter of the best answer in the blank.

_____ **1.** At a given temperature, the solubility of a gas in a liquid is: *18.1*
- **a.** proportional to the square root of the pressure of the gas above the liquid.
- **b.** directly proportional to the pressure of the gas above the liquid.
- **c.** inversely proportional to the pressure of the gas above the liquid.
- **d.** unrelated to the pressure of the gas above the liquid.

_____ **2.** If the addition of a crystal to an aqueous solution causes a great deal of dissolved solid to come out of solution, the original solution was: *18.1*
- **a.** a colloid.
- **b.** unsaturated.
- **c.** saturated.
- **d.** supersaturated.

_____ **3.** In general, as the temperature of a solution composed of a gas in a liquid is decreased, the solubility of the gas: *18.1*
- **a.** increases.
- **b.** decreases.
- **c.** remains the same.
- **d.** none of the above

_____ **4.** What is the molarity of a solution that contains 8 moles of solute in 2 L of solution? *18.2*
- **a.** 4*M*
- **b.** 8*M*
- **c.** 6*M*
- **d.** 0.25*M*

_____ **5.** To 225 mL of a 0.80*M* solution of KI, a student adds enough water to make 1 L of a more dilute KI solution. What is the molarity of the new solution? *18.2*
- **a.** 180*M*
- **b.** 0.18*M*
- **c.** 137 g
- **d.** 100 g

_____ **6.** How many milliliters of alcohol are in 167 mL of an 85.0% (v/v) alcohol solution? *18.2*
- **a.** 252 mL
- **b.** 228 mL
- **c.** 142 mL
- **d.** 145 mL

_____ **7.** Colligative properties depend on: *18.3*
- **a.** the nature of the solute.
- **b.** the nature of the solvent.
- **c.** the number of particles dissolved in a given mass of solvent.
- **d.** none of the above

_____ **8.** What is the freezing point of an aqueous 0.500*m* NaBr solution? (K_f for water = 1.86 °C/*m*) *18.4*
- **a.** −0.93 °C
- **b.** −1.86 °C
- **c.** −3.72 °C
- **d.** −9.30 °C

Name _____ Class _____ Date _____

18 SOLUTIONS
CHAPTER TEST A

A. Matching

Match each description in Column B with the correct term in Column A. Write the letter of the correct definition in the blank provided.

Column A	Column B
_____ **1.** saturated solution	**a.** At a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.
_____ **2.** colligative properties	**b.** a solution containing the maximum amount of solute that can be dissolved at a given temperature
_____ **3.** miscible	**c.** the number of moles of solute dissolved in 1 L of solution
_____ **4.** molarity	**d.** describes liquids that are insoluble in one another
_____ **5.** unsaturated solution	**e.** contains only a small amount of the maximum amount of solute that can be dissolved at a given temperature
_____ **6.** immiscible	**f.** contains less solute than can theoretically be dissolved
_____ **7.** concentrated solution	**g.** describes liquids that dissolve in each other
_____ **8.** Henry's law	**h.** contains more solute than can theoretically be held at a given temperature
_____ **9.** supersaturated solution	**i.** depend upon the number of particles of solute in solution
_____ **10.** dilute solution	**j.** a solution with a large amount of solute compared to solvent

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Increasing the temperature of a liquid–solid solution will:
- **a.** increase the rate at which a crystalline solute dissolves.
- **b.** increase the amount of crystalline solute that dissolves.
- **c.** both a and b
- **d.** neither a nor b

Name _____ Class _____ Date _____

_____ **12.** Which of the following operations usually makes a substance dissolve faster in a solvent?
a. agitation
b. raising the temperature
c. crushing the substance to a powder
d. all of the above

_____ **13.** To increase the solubility of a gas at constant temperature and 202 kPa pressure from 0.85 g/L to 5.1 g/L, the pressure would have to be increased to:
a. 1212 kPa.
b. 505 kPa.
c. 606 kPa.
d. 17.2 kPa.

_____ **14.** If the pressure of a gas above a liquid is decreased (at constant temperature), the solubility of the gas in the liquid:
a. remains unchanged.
b. increases.
c. decreases.
d. would change but in an unpredictable direction.

_____ **15.** An ionic compound has a solubility of 30 g per 100 mL of water at room temperature. A solution containing 70 g of the compound in 250 mL of water at the same temperature is:
a. saturated.
b. supersaturated.
c. unsaturated.
d. a suspension.

_____ **16.** How many mL of alcohol are in 240 mL of 95.0% (v/v) alcohol solution?
a. 12 mL
b. 228 mL
c. 145 mL
d. 142 mL

_____ **17.** If more solvent is added to a solution:
a. the molarity decreases.
b. the solution becomes less dilute.
c. the percent (v/v) increases.
d. all of the above

_____ **18.** What is the molarity of a 200 mL solution in which 0.2 mole of sodium bromide is dissolved?
a. 0.20*M*
b. 1.0*M*
c. 0.40*M*
d. 4.0*M*

_____ **19** What is the percent (m/v) of a water solution that contains 60 g of calcium chloride, $CaCl_2$, and that has a volume of 400 mL?
a. 15%
b. 1.35%
c. 24%
d. 6.7%

_____ **20.** Which of the following is *not* a colligative property of a solution?
a. boiling-point elevation
b. solubility
c. vapor-pressure lowering
d. freezing-point depression

Name _____ Class _____ Date _____

_____ **21.** If one mole of each of these solutes is added to the same amount of water, which solution has the highest boiling point?
- **a.** copper(II) chloride, $CuCl_2$
- **b.** glucose, $C_6H_{12}O_6$
- **c.** magnesium acetate, $Mg(C_2H_3O_2)_2$
- **d.** aluminum sulfate, $Al_2(SO_4)_3$

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true NT.

_____ **22.** The solubility of a solute can be increased by cooling the solvent.

_____ **23.** Grinding a solute increases the rate at which it would dissolve.

_____ **24.** As an open bottle of a carbonated beverage warms, the concentration of dissolved carbon dioxide decreases.

_____ **25.** One hundred mL of a 5.0*M* sodium chloride solution is more concentrated than 1.0 L of a 1.0*M* sodium chloride solution.

_____ **26.** The amount of sodium chloride in 100 mL of a 5.0*M* NaCl solution is greater than that in 1.0 L of a 1.0*M* NaCl solution.

_____ **27.** As the temperature of a solvent increases, the solubility of a gaseous solute increases.

_____ **28.** Fifty mL of a 16% solution (v/v) of ethyl alcohol in water contains 16 mL of water.

_____ **29.** An unsaturated solution contains less solute than required for equilibrium.

_____ **30.** A saturated solution has a large amount of solute compared to solvent.

_____ **31.** If a crystal of a substance added to aqueous solution dissolves, then the original solution containing that substance was supersaturated.

D. Problems

Solve the following problems in the space provided. Show your work.

32. How would you prepare 250 mL of 0.60*M* $Al_2(SO_4)_3$ solution from a 2.0*M* $Al_2(SO_4)_3$ stock solution?

Name _____ Class _____ Date _____

33. Calculate the molarity of a solution prepared by dissolving 95.5 g of KNO_3 in enough water to make 750 mL of solution.

34. A gas has a solubility in water of 16.9 g/L at 15 °C and 505 kPa of pressure. What is its solubility in water at 15 °C and 606 kPa of pressure?

E. Essay

Write a short essay for the following.

35. Explain on a particle basis how the addition of a solute affects the boiling point, freezing point, and vapor pressure of the solvent.

Name _____ Class _____ Date _____

F. Additional Problems

Solve the following problems in the space provided. Show your work.

36. Calculate the boiling point of a solution that contains 0.900 mol of K_3PO_4 dissolved in 2750 g of water. (K_b for water = 0.512 °C/*m*.)

37. Calculate the molality of a solution prepared by dissolving 175 g of KNO_3 in 1250 g of water.

38. A solution of 10.6 g of a nonvolatile compound in 55.0 g of water freezes at −3.26 °C. What is the molecular mass of the solute? (Assume that the solute exists as molecules in the solution. K_f for water = 1.86 °C/*m*)

Name _____ Class _____ Date _____

18 SOLUTIONS
CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A. Write the letter of the correct term in the blank provided.

Column A	Column B
_____ **1.** the number of moles of a solute dissolved in 1 L of solution	**a.** colligative properties
_____ **2.** the difference in temperature between the boiling points of a solution and of the pure solvent	**b.** Henry's law
_____ **3.** describes the ability of two liquids to dissolve in each other	**c.** boiling-point elevation
_____ **4.** the number of moles of solute dissolved in 1 kg of solvent	**d.** supersaturated solution
_____ **5.** a solution that contains more solute than it can theoretically hold at a given temperature	**e.** molality
_____ **6.** those properties of solutions that depend on the number of particles dissolved in a given mass of solvent	**f.** saturated solution
_____ **7.** a solution that contains the maximum amount of solute for a given amount of solvent at constant temperature	**g.** molarity
_____ **8.** the difference in temperature between the freezing points of a solution and of the pure solvent	**h.** miscible
_____ **9.** a measure of the amount of solute that is dissolved in a given quantity of solvent	**i.** freezing-point depression
_____ **10.** At a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.	**j.** concentration

B. Multiple Choice

Choose the best answer and write its letter in the blank.

_____ **11.** The rate at which a solute dissolves in a given solvent is determined by:
- **a.** the extent to which the solution is agitated.
- **b.** the temperature of the solution.
- **c.** the size of the solute particles.
- **d.** all of these

Name _____ Class _____ Date _____

_____ **12.** A glass of iced tea containing excess sugar at the bottom is said to be:
a. saturated. **c.** supersaturated.
b. unsaturated. **d.** homogeneous.

_____ **13.** If the solubility of $AgNO_3$ at 40 °C is 311 g per 100 g of water, what mass of this solute can be dissolved in 350 g of water at the same temperature?
a. 0.89 g **c.** 1.1 g
b. 1100 g **d.** 110 000 g

_____ **14.** In general, as the temperature of a solvent increases, the solubility of any gas dissolved within that solvent:
a. increases. **c.** remains the same.
b. decreases. **d.** cannot be predicted.

_____ **15.** Which of the following would increase the solubility of a gas in a liquid?
a. stirring the solution
b. increasing the temperature of the solvent
c. increasing the pressure of the gas above the solution
d. adding more solvent

_____ **16.** If the solubility of a gas in water is 1.22 g/L at 2.75 atm, what is its solubility (in g/L) at 1.0 atm?
a. 0.44 g/L **c.** 2.25 g/L
b. 3.97 g/L **d.** 3.36 g/L

_____ **17.** The most concentrated solution from among those listed is:
a. 100 mL 0.25*M* KCl. **c.** 75 mL 0.23*M* KNO_3.
b. 150 mL 0.18*M* NaOH. **d.** 200 mL 0.15*M* $NaNO_3$.

_____ **18.** The molarity of a solution that contains 14 g KOH per 150 mL of solution is:
a. 93*M*. **c.** 0.093*M*.
b. 1.7*M*. **d.** 11*M*.

_____ **19.** How many moles of solute are present in 1.25 L of a 0.75*M* $NaNO_3$ solution?
a. 1.7 mol **c.** 0.75 mol
b. 0.60 mol **d.** 0.94 mol

_____ **20.** What volume of 1.25*M* HCl would be required to prepare 180 mL of a 0.500*M* HCl solution?
a. 450 mL **c.** 0.014 mL
b. 72 mL **d.** 2.2×10^{-3} mL

_____ **21.** What is the percent (m/v) of a solution containing 25 g of NaCl in 175 mL of solution?
a. 700% **c.** 7.0%
b. 0.14% **d.** 14%

_____ **22.** Which of the following results from the presence of a solute in a given solvent?
- **a.** The vapor pressure of the solution is lower than that of the pure solvent.
- **b.** The boiling point of the solution is lower than that of the pure solvent.
- **c.** The freezing point of the solution is higher than that of the pure solvent.
- **d.** all of these

_____ **23.** What is the molality of a solution prepared by dissolving 13.0 g of $Ba(NO_3)_2$ in 450 g of water?
- **a.** 0.029 molal
- **b.** 29 molal
- **c.** 0.11 molal
- **d.** 1.1×10^{-4} molal

_____ **24.** The mole fraction of ethanol in a solution containing 1.50 moles of ethanol and 3.25 mol of water is:
- **a.** 0.316
- **b.** 0.217
- **c.** 0.462
- **d.** 0.681

_____ **25.** The addition of antifreeze to water in a car radiator causes the freezing point of the mixture to:
- **a.** increase.
- **b.** decrease.
- **c.** remain the same.
- **d.** vary unpredictably.

_____ **26.** What is the molality of an aqueous solution of a molecular solute if the boiling point of the solution is 101.4 °C?
- **a.** 2.70 molal
- **b.** 0.515 molal
- **c.** 1.04 molal
- **d.** 0.556 molal

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true NT.

_____ **27.** Whether a solute dissolves in a given solvent is determined by the nature of the two substances.

_____ **28.** Stirring a solution at constant temperature increases the amount of solute that can be dissolved.

_____ **29.** At constant temperature, more powdered sugar will dissolve in a cup of coffee than will sugar that is in the form of cubes.

_____ **30.** Oil and water are completely miscible.

_____ **31.** Increasing the temperature increases the solubility of a given substance.

_____ **32.** A 2.5*M* solution of KNO_3 contains 2.5 moles solute particles per 1 kg of solvent.

_____ **33.** The number of moles of solute in a given solution decreases as the solution is diluted.

Name _____ Class _____ Date _____

_____ **34.** A solution has a lower vapor pressure than that of the solvent contained within it.

_____ **35.** The boiling point of a solution is lower than that of the pure solvent.

_____ **36.** The freezing point of a 1.0 molal solution of $MgCl_2$ is 5.58 °C lower than that of pure water.

D. Problems

Solve the following problems in the space provided. Show your work.

37. If a saturated solution of $AgNO_3$ at 20 °C contains 216 g $AgNO_3$ per 100.0 g of water, what mass of water could contain 725 g of this solute at the same temperature?

38. At 10 °C, the solubility of a gas in water is 2.45 g/L at 0.750 atm. What pressure would be required to produce an aqueous solution containing 6.25 g/L of this gas at 10 °C?

39. Calculate the molarity of a solution that contains 50.0 g of $Mg(NO_3)_2$ per 225 mL of solution.

40. What mass of $AgNO_3$ would be required to prepare a 0.250 molal solution in 125 g of water?

Name _____ Class _____ Date _____

E. Essay

Wrtie a short essay for the following

41. Often during the winter, salt is sprinkled on bridges and sidewalks. Explain the purpose for doing so and the reasons why salt is effective for this purpose.

F. Additional Problems

Solve the following problems in the space provided. Show your work.

42. What mass of H_2SO_4 would be required to prepare 750 mL of a 0.15*M* H_2SO_4 solution?

43. Determine the freezing point of a solution made by adding 27.5 g of methanol (CH_3OH) to 250.0 g of water.

44. What is the boiling point of an aqueous solution that contains 62.5 g of $Ba(NO_3)_2$ in 750.0 g of water?

Name _____ Class _____ Date _____

45. Ether has a molal freezing point constant of 1.79 °C/*m*. When 31.8 g of an unknown molecular solute is dissolved in 1110 g of ether, the resulting solution has a freezing point depression of 0.570 °C. What is the molecular mass of the solute?

18 SOLUTIONS
PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
18.1 Properties of Solutions **Objectives** ▸ Identify the factors that determine the rate at which a solute dissolves ▸ Calculate the solubility of a gas in a liquid under various pressure conditions	**Discover It!** *Salt and the Freezing Point of Water,* p. 500 **Link to Agriculture** *Fertilizer Runoff,* 502 **Sample Problem** 18-1 **Mini Lab** *Solutions and Colloids,* p. 508	**Review Module** (Chapters 17–20) ▸ Section Review 18.1 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheet** 18-1 **Laboratory Manual** ▸ Experiment 30: *Factors Affecting Solution Formation* ▸ Experiment 31: *Supersaturation* **Laboratory Practical** 18-1 **Small-Scale Chemistry Lab Manual,** Experiment 23: *Solubility Rules*
18.2 Concentrations of Solutions **Objectives** ▸ Solve problems involving the molarity of a solution ▸ Describe how to prepare dilute solutions from more-concentrated solutions of known molarity ▸ Explain what is meant by percent by volume (% (v/v)) and percent by mass (% (m/v)) solutions	**Link to Nursing** *Intravenous Solutions,* p. 510 **Sample Problems** 18-2 through 18-6 **Small-Scale Lab** *Making a Solution,* p. 516	**Review Module** ▸ Section Review 18.2 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheet** 18-2 **Laboratory Manual,** Experiment 32: *Chromatography*
18.3 Colligative Properties of Solutions **Objectives** ▸ Explain on a particle basis why a solution has a lower vapor pressure than the pure solvent of that solution ▸ Explain on a particle basis why a solution has an elevated boiling point and a depressed freezing point compared to the pure solvent		**Review Module** ▸ Section Review 18.3 ▸ Practice Problems ▸ Quizzes **Laboratory Manual,** Experiment 33: *Freezing Point*
18.4 Calculations Involving Colligative Properties **Objectives** ▸ Calculate the molality and mole fraction of a solution ▸ Calculate the molar mass of a molecular compound from the freezing-point depression or boiling-point elevation of a solution of the compound	**Sample Problems** 18-7 through 18-10 **Chemistry Serving . . . Society** *A Solution for Kidney Failure,* p. 526 **Chemistry in Careers** *Nephrology Nurse,* p. 526	**Review Module** ▸ Section Review 18.4 ▸ Practice Problems ▸ Vocabulary Review 18 ▸ Chapter 18 Tests and Quizzes **Laboratory Manual,** Experiment 33: *Freezing Point* **Solutions Manual for Chapter Reviews** **Graphing Calculator Problems**

TECHNOLOGY RESOURCES

Internet Connections
Within this chapter, you will see the chemSURF logo. If you and your students have access to the Internet, the following URL address will provide various Internet connections that are related to topics and features presented in this chapter.

http://www.chemsurf.com

You can also find relevant chapter material at
The Chemistry Place address:
http://www.chemplace.com

CD-ROMs

Chem ASAP! CD-ROM
- Chapter 18

ResourcePro CD-ROM
- Chapter 18

ActivChemistry CD-ROM
- Properties of Solutions

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Big Bottle Shake
- Molarity

Overhead Transparencies
- #60: Dynamic Equilibrium
- #61: Solubility and Temperature
- #62: Concentrated and Dilute Solutions

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 500
- plastic plates
- string or narrow ribbon
- water
- ice cubes
- table salt

Mini Lab p. 508
- sodium hydrogen carbonate
- cornstarch
- distilled water (or tap water)
- flashlights
- black construction paper
- masking tape
- jars with parallel sides
- teaspoons
- cups

Small-Scale Lab, p. 516
- solid NaCl
- water
- 50-mL plastic volumetric bottles
- balances

TEACHER'S EDITION

Teacher Demo, p. 505
- bottle of warm soda
- bottle of cold soda
- 2 other bottles of soda

Activity, p. 511
- 500 mL of water
- volumetric flask
- NaCl
- 0.0625*M*, 0.125*M*, 0.250*M*, and 0.500*M* solutions of sucrose
- 100-mL and 50-mL volumetric flasks

Teacher Demo, p. 514
- four 20-mL test tubes
- 10 mL of 0.5*M* sucrose for one test tube
- 5 mL water for each of the other test tubes
- 10-mL pipet

Activity, p. 519
- ice water
- rock salt
- thermometer
- Styrofoam cup

Activity, p. 524
- different concentrations of an NaCl or ethylene glycol solution
- thermometers

ASSESSMENT

Student Edition
- Section Reviews 18.1–18.4
- Chapter 18 Review, pp. 527–530
- Alternative Assessment, p. 531

Technology
Chem ASAP! CD-ROM
- Assessment 18.1–18.4

Assessment Resources CD-ROM
- Chapter 18 Tests

Teacher's Resource Package
Review Module (Chap. 17–20)
- Vocabulary Review
- Chapter 18 Test A and Test B
- Chapter 18 Quizzes

Name _____ Class _____ Date _____

18.1 PROPERTIES OF SOLUTIONS
SECTION REVIEW

Objectives

- Identify the factors that determine the rate at which a solute dissolves
- Calculate the solubility of a gas in a liquid under various pressure conditions

Key Terms

- saturated solution
- solubility
- unsaturated
- miscible
- immiscible
- Henry's law
- supersaturated solution

Key Equation

- Henry's law: $\frac{S_1}{P_1} = \frac{S_2}{P_2}$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

Changes in the temperature of a system and __1__ of a solute alter the __2__ at which a solute dissolves. The extent to which a gas dissolves in a liquid is proportional to the __3__ of the gas in accordance with __4__ law. The solubility of a gas decreases with __5__ temperature. A solution that contains the maximum amount of solute at a given temperature is said to be __6__. Two liquids that are mutually soluble in each other are said to be __7__. Generally the __8__ of a solid in water __9__ with increasing temperature, but there are exceptions. A __10__ solution holds more solute than theoretically possible.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** The rate at which a solute dissolves can be increased by grinding.

_____ **12.** As the temperature of a solvent decreases, the solubility of a solute increases.

_____ **13.** Stirring a solute when adding it to a solvent should increase the rate of its dissolving.

_____ **14.** Henry's law states that the solubility of a gas in a liquid is a function of temperature.

_____ **15.** Two liquids which dissolve in each other are miscible.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **16.** saturated solution	**a.** the amount of a substance that dissolves in a given quantity of solvent at a given temperature
_____ **17.** solubility	**b.** The solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.
_____ **18.** unsaturated	**c.** solution that contains the maximum amount of solute for a given amount of solvent at a constant temperature
_____ **19.** miscible	**d.** a solution containing more solute than it can theoretically hold at a given temperature
_____ **20.** immiscible	**e.** description of two liquids that dissolve in each other
_____ **21.** Henry's law	**f.** a solution that contains less solute than possible at a given temperature
_____ **22.** supersaturated solution	**g.** description of two liquids that do not dissolve in each other

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

23. The solubility of a gas in water is 1.6 g/L at 1.0 atm of pressure. What is the solubility of the same gas at 2.5 atm? Assume the temperature to be constant.

Name _____ Class _____ Date _____

18.2 CONCENTRATIONS OF SOLUTIONS
SECTION REVIEW

Objectives

- Solve problems involving the molarity of a solution
- Describe how to prepare dilute solutions from more concentrated solutions of known molarity
- Explain what is meant by percent by volume [%(v/v)] and percent by mass [%(m/v)] solutions

Key Terms

- concentration
- dilute solution
- concentrated solution
- molarity (M)

Key Equations

- Molarity (M) $= \dfrac{\text{moles of solute}}{\text{liters of solution}}$
- $M_1 \times V_1 = M_2 \times V_2$
- Percent by volume [%(v/v)] $= \dfrac{\text{volume of solute}}{\text{solution volume}} \times 100\%$
- Percent (mass/volume)[%(m/v)] $= \dfrac{\text{mass of solute (g)}}{\text{solution volume (mL)}} \times 100\%$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

The relative amounts of solute and __1__ in a __2__ can be described qualitatively as __3__ or concentrated. Quantitative units of concentration include molar concentration, percent by volume, and percent (mass/volume).

Molarity, the most important unit of concentration in chemistry, is expressed as __4__ of solute per __5__ of solution.

Solutions of different concentrations can be prepared by __6__ a stock solution. In dilution, the moles of __7__ remain the same, while the amount of __8__ changes.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **9.** One hundred mL of 1.0*M* sodium hydroxide solution is more concentrated than 1.0 L of 5*M* sodium hydroxide solution.

_____ **10.** The amount of sodium hydroxide in 100 mL of 1.0*M* NaOH is less than that in 1.0 L of 5*M* NaOH solution.

_____ **11.** Fifty mL of a 32% solution (v/v) of ethyl alcohol in water would contain 42 mL of water.

_____ **12.** A dilute solution is a quantitative expression of concentration.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **13.** concentration	**a.** number of moles of solute dissolved in 1 L of solution
_____ **14.** dilute solution	**b.** measure of the amount of solute that is dissolved in a given quantity of solvent
_____ **15.** concentrated solution	**c.** solution that contains a low concentration of solute
_____ **16.** molarity	**d.** concentration expressed as volume or mass of solute over volume of solution × 100%
_____ **17.** percent solution	**e.** solution that contains a high concentration of solute

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

18. What mass of sucrose, $C_{12}H_{22}O_{11}$, is needed to make 300.0 mL of a 0.50*M* solution?

Name _____ Class _____ Date _____

18.3 COLLIGATIVE PROPERTIES OF SOLUTIONS
SECTION REVIEW

Objectives

- Explain on a particle basis why a solution has a lower vapor pressure than the pure solvent of that solution
- Explain on a particle basis why a solution has an elevated boiling point and a depressed freezing point compared with the pure solvent

Key Terms

- colligative properties
- boiling-point elevation
- freezing-point depression

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

The effects in solution of a nonvolatile __1__ on the properties of the solvent are called __2__. They include __3__ point and vapor pressure __4__, and boiling point __5__. In each case, the magnitude of the effect is __6__ proportional to the number of solute molecules or ions present in the __7__.

Colligative properties are a function of the number of solute __8__ in solution. For example, one mole of sodium chloride produces __9__ as many particles in solution as one mole of sucrose and, thus, will depress the freezing point of water __10__ as much.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** When added to 1000 g of water, 2 moles of a solute will increase the boiling point by 0.512 °C.

_____ **12.** One mole of solute A will depress the freezing point of 1000 g of water the same as one mole of solute B.

Name _____ Class _____ Date _____

_____ **13.** Addition of a nonvolatile solute will lower the boiling point of a solvent.

_____ **14.** Addition of a nonvolatile solute will lower the freezing point of a solvent.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** colligative properties	**a.** difference between the freezing point of a solution and the freezing point of the pure solvent
_____ **16.** boiling-point elevation	**b.** pressure exerted by a vapor that is in equilibrium with its liquid in a closed system
_____ **17.** freezing-point depression	**c.** difference between the boiling point of a solution and the boiling point of the pure solvent
_____ **18.** vapor pressure	**d.** properties of solutions that depend only on the number of particles in solution

Part D Questions and Problems

Answer the following questions in the space provided.

19. How many moles of solute particles are produced by adding one mole of each of the following to water?

a. sodium nitrate

b. glucose

c. aluminum chloride

d. potassium iodide

20. An equal number of moles of NaCl and K_2CO_3 are dissolved in equal volumes of water. Which solution has the higher

a. boiling point?

b. vapor pressure?

c. freezing point?

Name _____ Class _____ Date _____

18.4 CALCULATIONS INVOLVING COLLIGATIVE PROPERTIES
SECTION REVIEW

Objectives

- Calculate the molality and mole fraction of a solution
- Calculate the molar mass of a molecular compound from the freezing-point depression or boiling-point elevation of a solution of the compound

Key Terms

- molality (m)
- mole fraction
- molal boiling-point elevation constant (K_b)
- molal freezing-point depression constant (K_f)

Key Equations

- $\text{Molality} = \dfrac{\text{moles of solute}}{\text{kilogram of solvent}} = \dfrac{\text{moles of solute}}{1000\text{ g of solvent}}$
- mole fractions: $X_A = \dfrac{n_A}{n_A + n_B}$ $\quad X_B = \dfrac{n_B}{n_A + n_B}$
  where n_A = moles of solute
  n_B = moles of solvent
- $\Delta T_b = K_b \times m$
- $\Delta T_f = K_f \times m$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

Molality is an expression of concentration involving the ratio of __1__ particles to __2__ particles. Molality is expressed as moles of solute per __3__ of solvent.

Another expression of concentration is __4__, in which concentrations are expressed as the ratio of moles of solute to the total number of moles of solvent and solute. Each solvent has a characteristic __5__ elevation constant and molal freezing-point __6__ constant. The elevation in boiling point of a solution can be calculated by multiplying the __7__ concentration of the solution by the boiling-point __8__ constant of the solvent.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **9.** It is possible to calculate the molar mass of a solute if you know the K_b or K_f of a solvent.

_____ **10.** Molal concentration is the same as molar concentration.

_____ **11.** The depression in freezing point of a solution is proportional to the molal concentration of solute.

_____ **12.** The sum of X_A and X_B for any solution is always 1.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **13.** molality	**a.** a constant for a given solvent equal to the change in boiling point for a 1*m* solution
_____ **14.** mole fraction	**b.** number of moles of solute dissolved in 1 kilogram of solvent
_____ **15.** molal boiling-point elevation constant	**c.** mass of one mole of a substance
_____ **16.** molal freezing-point depression constant	**d.** a constant for a given solvent equal to the change in freezing point for a 1*m* solution
_____ **17.** molar mass	**e.** ratio of moles of solute in solution to the total number of moles of solute and solvent

Part D Questions and Problems

Solve the following problem in the space provided. Show your work.

18. What is the freezing point of a solution that contains 2.0 mol of $CaCl_2$ in 800.0 g of water? K_f for water = 1.86 °C/*m*

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18 SOLUTIONS
PRACTICE PROBLEMS

Read each question or statement and respond in your notebook.

SECTION 18.1 PROPERTIES OF SOLUTIONS

1. The solubility of CO_2 in water at 1.22 atm is 0.54 g/L. What is the solubility of carbon dioxide at 1.86 atm? Assume that temperature is constant.
2. What mass of KCl will produce a saturated solution in 500.0 g of water at 20 °C?
3. A saturated solution of silver nitrate is prepared in 100.0 g of water at 20 °C. The solution is then heated to 50.0 °C. How much more silver nitrate must now be added to obtain a saturated solution?

SECTION 18.2 CONCENTRATIONS OF SOLUTIONS

1. Calculate the molarity of each of the following solutions.
   a. 0.40 mol of NaCl dissolved in 1.6 L of solution
   b. 20.2 g of potassium nitrate, KNO_3, in enough water to make 250.0 mL of solution
2. Calculate the number of grams of solute needed to prepare each of the following solutions.
   a. 2500.0 mL of a 3.0*M* solution of potassium hydroxide, KOH
   b. 2.0 liters of 2.0*M* nitric acid, HNO_3, solution
3. What is the molarity of a solution that contains 212.5 g of sodium nitrate ($NaNO_3$) in 3.0 liters of solution?
4. You must prepare 300.0 mL of 0.750*M* NaBr solution using 2.00*M* NaBr stock solution. How many milliliters of stock solution should you use?
5. In order to dilute 1.0 L of a 6.00*M* solution of NaOH to 0.500*M* solution, how much water must you add?
6. What is the concentration in percent by volume, %(v/v), of the following solutions?
   a. 60.0 mL of methanol in a total volume of 500.0 mL
   b. 25.0 mL of rubbing alcohol (C_3H_7OH) diluted to a volume of 200.0 mL with water
7. How many grams of solute are needed to prepare each of the following solutions?
   a. 1.00 L of a 3.00% (m/v) NaCl solution?
   b. 2.00 L of 5.00% (m/v) KNO_3 solution?

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SECTION 18.3 COLLIGATIVE PROPERTIES OF SOLUTIONS

1. What are colligative properties of solutions? Give examples of three types of colligative properites.
2. How many particles in solution are produced by each formula unit of potassium carbonate, K_2CO_3?
3. How may moles of particles would 3 mol Na_2SO_4 give in solution?
4. What is the boiling point of a solution that contains 2 mol of magnesium chloride in 100.0 g of water?
5. What kind of property is vapor-pressure lowering?
6. An equal number of moles of NaCl and $CaCl_2$ are dissolved in equal volumes of water. Which solution has the lower
   a. freezing point?
   b. vapor pressure?
   c. boiling point?

SECTION 18.4 CALCULATIONS INVOLVING COLLIGATIVE PROPERTIES

1. Calculate the mole fraction of solute in each of the following solutions.
   a. 3.0 moles of lithium bromide, LiBr, dissolved in 6.0 moles of water
   b. 125.0 g of potassium nitrate, KNO_3, dissolved in 800.0 g of water
2. How many grams of sodium chloride must dissolve in 750.0 g of water to make a 0.50 molal solution?
3. How many grams of lithium sulfide must be dissolved in 1600.0 g of water to make a 2.0 molal solution?
4. Find the molality of each of the following solutions.
   a. 2.3 moles of glucose dissolved in 500.0 g of water
   b. 131 g of $Ba(NO_3)_2$ dissolved in 750.0 g of water
5. Find the boiling points of the following solutions.
   a. 2.00*m* solution of sodium chloride, NaCl
   b. 1.50*m* solution of calcium chloride, $CaCl_2$
6. Find the freezing points of the following solutions.
   a. 0.35 moles of sodium chloride, NaCl, dissolved in 900.0 g of water
   b. 126.0 g of table sugar, $C_{12}H_{22}O_{11}$, dissolved in 2500.0 g of water
7. A solution of 4.69 g of a nonvolatile compound in 16.00 g of water boils at 100.83 °C at 760 mm Hg. What is the molar mass of the solute? Assume that the solute exists as molecules not ions.

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18 INTERPRETING GRAPHICS

USE WITH SECTION 18.1

Solubilities of Some Substances in Water at Various Temperatures					
		Solubility (g/100 g of H_2O)			
Substance	**Formula**	**0 °C**	**20 °C**	**50 °C**	**100 °C**
Barium hydroxide	$Ba(OH)_2$	1.67	31.89	—	—
Barium sulfate	$BaSO_4$	0.00019	0.00025	0.00034	—
Calcium hydroxide	$Ca(OH)_2$	0.189	0.173	—	0.07
Lead(II) chloride	$PbCl_2$	0.60	0.99	1.70	—
Lithium carbonate	Li_2CO_3	1.5	1.3	1.1	0.70
Potassium chlorate	$KClO_3$	4.0	7.4	19.3	56.0
Potassium chloride	KCl	27.6	34.0	42.6	57.6
Sodium chloride	NaCl	35.7	36.0	37.0	39.2
Sodium nitrate	$NaNO_3$	74	88.0	114.0	182
Sodium sulfate	Na_2SO_4	4.76	62	50.0	41.0
Silver nitrate	$AgNO_3$	122	222.0	455.0	733
Lithium bromide	LiBr	143.0	166	203	266.0
Cane sugar (sucrose)	$C_{12}H_{22}O_{11}$	179	230.9	260.4	487

A portion of Table 18.1 from your textbook has been reproduced above. Use the table to answer the following questions.

1. Saturated solutions of each of the following compounds are made at 20 °C. Circle the letter(s) of the solution(s) which will form a precipitate upon heating.

   a. NaCl

   b. Na_2SO_4

   c. Li_2CO_3

   d. sucrose

2. A saturated solution of potassium chloride is prepared in 100.0 g of water at 20 °C. If the solution is heated to 50 °C, how much more KCl must be added to obtain a saturated solution?

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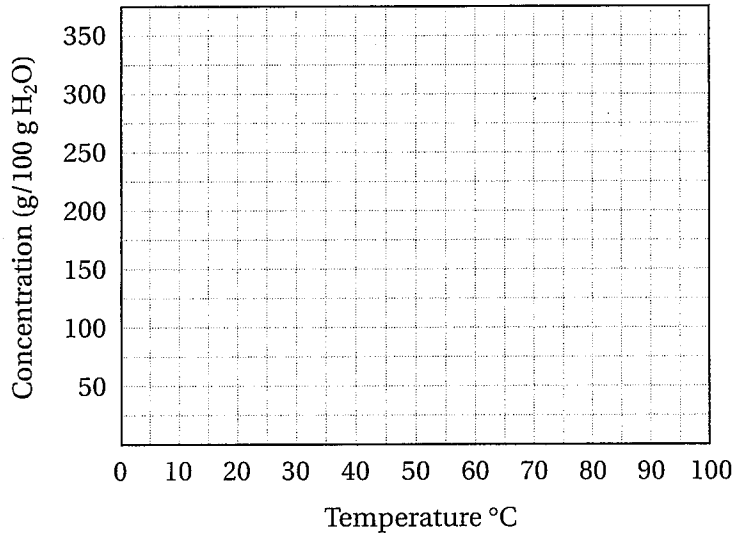
3. A saturated solution of sucrose in 1000.0 g of boiling water is cooled to 20 °C. What mass of rock candy will be formed?

4. Using data from the table, plot the solubility curves of KCl, LiBr and Na_2SO_4 on the graph below. Be sure to label each curve. Use the graph to answer the following questions.



a. Which of the compounds is most soluble at 25 °C?

_____

_____

b. Which of the compounds has the lowest solubility at 90 °C?

_____

_____

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18 VOCABULARY REVIEW

From each group of terms, choose the term that does not belong and then explain your choice.

1. saturated, unsaturated, molarity, supersaturated

2. miscible, immiscible, concentration

3. molarity, mole fraction, molality, Henry's law

4. solubility of a gas, Henry's law, pressure, colligative properties

5. colligative properties, saturated solution, freezing-point depression, molality

6. molal freezing-point depression constant (K_f), colligative properties, ice cream, molarity

7. surface area, mole fraction, temperature, stirring

8. dilute solution, concentrated solution, $M_1 \times V_1 = M_2 \times V_2$, boiling-point elevation

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18 SOLUTIONS

Quiz for CHAPTER 18

Write the letter of the best answer in the blank.

_____ **1.** At a given temperature, the solubility of a gas in a liquid is: *18.1*
- **a.** proportional to the square root of the pressure of the gas above the liquid.
- **b.** directly proportional to the pressure of the gas above the liquid.
- **c.** inversely proportional to the pressure of the gas above the liquid.
- **d.** unrelated to the pressure of the gas above the liquid.

_____ **2.** If the addition of a crystal to an aqueous solution causes a great deal of dissolved solid to come out of solution, the original solution was: *18.1*
- **a.** a colloid.
- **b.** unsaturated.
- **c.** saturated.
- **d.** supersaturated.

_____ **3.** In general, as the temperature of a solution composed of a gas in a liquid is decreased, the solubility of the gas: *18.1*
- **a.** increases.
- **b.** decreases.
- **c.** remains the same.
- **d.** none of the above

_____ **4.** What is the molarity of a solution that contains 8 moles of solute in 2 L of solution? *18.2*
- **a.** 4*M*
- **b.** 8*M*
- **c.** 6*M*
- **d.** 0.25*M*

_____ **5.** To 225 mL of a 0.80*M* solution of KI, a student adds enough water to make 1 L of a more dilute KI solution. What is the molarity of the new solution? *18.2*
- **a.** 180*M*
- **b.** 0.18*M*
- **c.** 137 g
- **d.** 100 g

_____ **6.** How many milliliters of alcohol are in 167 mL of an 85.0% (v/v) alcohol solution? *18.2*
- **a.** 252 mL
- **b.** 228 mL
- **c.** 142 mL
- **d.** 145 mL

_____ **7.** Colligative properties depend on: *18.3*
- **a.** the nature of the solute.
- **b.** the nature of the solvent.
- **c.** the number of particles dissolved in a given mass of solvent.
- **d.** none of the above

_____ **8.** What is the freezing point of an aqueous 0.500*m* NaBr solution? (K_f for water = 1.86 °C/*m*) *18.4*
- **a.** −0.93 °C
- **b.** −1.86 °C
- **c.** −3.72 °C
- **d.** −9.30 °C

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18 SOLUTIONS
CHAPTER TEST A

A. Matching

Match each description in Column B with the correct term in Column A. Write the letter of the correct definition in the blank provided.

Column A	Column B
_____ **1.** saturated solution	**a.** At a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.
_____ **2.** colligative properties	**b.** a solution containing the maximum amount of solute that can be dissolved at a given temperature
_____ **3.** miscible	**c.** the number of moles of solute dissolved in 1 L of solution
_____ **4.** molarity	**d.** describes liquids that are insoluble in one another
_____ **5.** unsaturated solution	**e.** contains only a small amount of the maximum amount of solute that can be dissolved at a given temperature
_____ **6.** immiscible	**f.** contains less solute than can theoretically be dissolved
_____ **7.** concentrated solution	**g.** describes liquids that dissolve in each other
_____ **8.** Henry's law	**h.** contains more solute than can theoretically be held at a given temperature
_____ **9.** supersaturated solution	**i.** depend upon the number of particles of solute in solution
_____ **10.** dilute solution	**j.** a solution with a large amount of solute compared to solvent

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Increasing the temperature of a liquid–solid solution will:
- **a.** increase the rate at which a crystalline solute dissolves.
- **b.** increase the amount of crystalline solute that dissolves.
- **c.** both a and b
- **d.** neither a nor b

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_____ **12.** Which of the following operations usually makes a substance dissolve faster in a solvent?
a. agitation
b. raising the temperature
c. crushing the substance to a powder
d. all of the above

_____ **13.** To increase the solubility of a gas at constant temperature and 202 kPa pressure from 0.85 g/L to 5.1 g/L, the pressure would have to be increased to:
a. 1212 kPa.
b. 505 kPa.
c. 606 kPa.
d. 17.2 kPa.

_____ **14.** If the pressure of a gas above a liquid is decreased (at constant temperature), the solubility of the gas in the liquid:
a. remains unchanged.
b. increases.
c. decreases.
d. would change but in an unpredictable direction.

_____ **15.** An ionic compound has a solubility of 30 g per 100 mL of water at room temperature. A solution containing 70 g of the compound in 250 mL of water at the same temperature is:
a. saturated.
b. supersaturated.
c. unsaturated.
d. a suspension.

_____ **16.** How many mL of alcohol are in 240 mL of 95.0% (v/v) alcohol solution?
a. 12 mL
b. 228 mL
c. 145 mL
d. 142 mL

_____ **17.** If more solvent is added to a solution:
a. the molarity decreases.
b. the solution becomes less dilute.
c. the percent (v/v) increases.
d. all of the above

_____ **18.** What is the molarity of a 200 mL solution in which 0.2 mole of sodium bromide is dissolved?
a. 0.20*M*
b. 1.0*M*
c. 0.40*M*
d. 4.0*M*

_____ **19** What is the percent (m/v) of a water solution that contains 60 g of calcium chloride, $CaCl_2$, and that has a volume of 400 mL?
a. 15%
b. 1.35%
c. 24%
d. 6.7%

_____ **20.** Which of the following is *not* a colligative property of a solution?
a. boiling-point elevation
b. solubility
c. vapor-pressure lowering
d. freezing-point depression

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_____ **21.** If one mole of each of these solutes is added to the same amount of water, which solution has the highest boiling point?
- **a.** copper(II) chloride, $CuCl_2$
- **b.** glucose, $C_6H_{12}O_6$
- **c.** magnesium acetate, $Mg(C_2H_3O_2)_2$
- **d.** aluminum sulfate, $Al_2(SO_4)_3$

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true NT.

_____ **22.** The solubility of a solute can be increased by cooling the solvent.

_____ **23.** Grinding a solute increases the rate at which it would dissolve.

_____ **24.** As an open bottle of a carbonated beverage warms, the concentration of dissolved carbon dioxide decreases.

_____ **25.** One hundred mL of a 5.0*M* sodium chloride solution is more concentrated than 1.0 L of a 1.0*M* sodium chloride solution.

_____ **26.** The amount of sodium chloride in 100 mL of a 5.0*M* NaCl solution is greater than that in 1.0 L of a 1.0*M* NaCl solution.

_____ **27.** As the temperature of a solvent increases, the solubility of a gaseous solute increases.

_____ **28.** Fifty mL of a 16% solution (v/v) of ethyl alcohol in water contains 16 mL of water.

_____ **29.** An unsaturated solution contains less solute than required for equilibrium.

_____ **30.** A saturated solution has a large amount of solute compared to solvent.

_____ **31.** If a crystal of a substance added to aqueous solution dissolves, then the original solution containing that substance was supersaturated.

D. Problems

Solve the following problems in the space provided. Show your work.

32. How would you prepare 250 mL of 0.60*M* $Al_2(SO_4)_3$ solution from a 2.0*M* $Al_2(SO_4)_3$ stock solution?

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33. Calculate the molarity of a solution prepared by dissolving 95.5 g of KNO_3 in enough water to make 750 mL of solution.

34. A gas has a solubility in water of 16.9 g/L at 15 °C and 505 kPa of pressure. What is its solubility in water at 15 °C and 606 kPa of pressure?

E. Essay

Write a short essay for the following.

35. Explain on a particle basis how the addition of a solute affects the boiling point, freezing point, and vapor pressure of the solvent.

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F. Additional Problems

Solve the following problems in the space provided. Show your work.

36. Calculate the boiling point of a solution that contains 0.900 mol of K_3PO_4 dissolved in 2750 g of water. (K_b for water = 0.512 °C/*m*.)

37. Calculate the molality of a solution prepared by dissolving 175 g of KNO_3 in 1250 g of water.

38. A solution of 10.6 g of a nonvolatile compound in 55.0 g of water freezes at −3.26 °C. What is the molecular mass of the solute? (Assume that the solute exists as molecules in the solution. K_f for water = 1.86 °C/*m*)

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18 SOLUTIONS
CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A. Write the letter of the correct term in the blank provided.

Column A	Column B
_____ **1.** the number of moles of a solute dissolved in 1 L of solution	**a.** colligative properties
_____ **2.** the difference in temperature between the boiling points of a solution and of the pure solvent	**b.** Henry's law
_____ **3.** describes the ability of two liquids to dissolve in each other	**c.** boiling-point elevation
_____ **4.** the number of moles of solute dissolved in 1 kg of solvent	**d.** supersaturated solution
_____ **5.** a solution that contains more solute than it can theoretically hold at a given temperature	**e.** molality
_____ **6.** those properties of solutions that depend on the number of particles dissolved in a given mass of solvent	**f.** saturated solution
_____ **7.** a solution that contains the maximum amount of solute for a given amount of solvent at constant temperature	**g.** molarity
_____ **8.** the difference in temperature between the freezing points of a solution and of the pure solvent	**h.** miscible
_____ **9.** a measure of the amount of solute that is dissolved in a given quantity of solvent	**i.** freezing-point depression
_____ **10.** At a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.	**j.** concentration

B. Multiple Choice

Choose the best answer and write its letter in the blank.

_____ **11.** The rate at which a solute dissolves in a given solvent is determined by:
- **a.** the extent to which the solution is agitated.
- **b.** the temperature of the solution.
- **c.** the size of the solute particles.
- **d.** all of these

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_____ **12.** A glass of iced tea containing excess sugar at the bottom is said to be:
a. saturated. **c.** supersaturated.
b. unsaturated. **d.** homogeneous.

_____ **13.** If the solubility of $AgNO_3$ at 40 °C is 311 g per 100 g of water, what mass of this solute can be dissolved in 350 g of water at the same temperature?
a. 0.89 g **c.** 1.1 g
b. 1100 g **d.** 110 000 g

_____ **14.** In general, as the temperature of a solvent increases, the solubility of any gas dissolved within that solvent:
a. increases. **c.** remains the same.
b. decreases. **d.** cannot be predicted.

_____ **15.** Which of the following would increase the solubility of a gas in a liquid?
a. stirring the solution
b. increasing the temperature of the solvent
c. increasing the pressure of the gas above the solution
d. adding more solvent

_____ **16.** If the solubility of a gas in water is 1.22 g/L at 2.75 atm, what is its solubility (in g/L) at 1.0 atm?
a. 0.44 g/L **c.** 2.25 g/L
b. 3.97 g/L **d.** 3.36 g/L

_____ **17.** The most concentrated solution from among those listed is:
a. 100 mL 0.25*M* KCl. **c.** 75 mL 0.23*M* KNO_3.
b. 150 mL 0.18*M* NaOH. **d.** 200 mL 0.15*M* $NaNO_3$.

_____ **18.** The molarity of a solution that contains 14 g KOH per 150 mL of solution is:
a. 93*M*. **c.** 0.093*M*.
b. 1.7*M*. **d.** 11*M*.

_____ **19.** How many moles of solute are present in 1.25 L of a 0.75*M* $NaNO_3$ solution?
a. 1.7 mol **c.** 0.75 mol
b. 0.60 mol **d.** 0.94 mol

_____ **20.** What volume of 1.25*M* HCl would be required to prepare 180 mL of a 0.500*M* HCl solution?
a. 450 mL **c.** 0.014 mL
b. 72 mL **d.** 2.2×10^{-3} mL

_____ **21.** What is the percent (m/v) of a solution containing 25 g of NaCl in 175 mL of solution?
a. 700% **c.** 7.0%
b. 0.14% **d.** 14%

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_____ **22.** Which of the following results from the presence of a solute in a given solvent?
- **a.** The vapor pressure of the solution is lower than that of the pure solvent.
- **b.** The boiling point of the solution is lower than that of the pure solvent.
- **c.** The freezing point of the solution is higher than that of the pure solvent.
- **d.** all of these

_____ **23.** What is the molality of a solution prepared by dissolving 13.0 g of $Ba(NO_3)_2$ in 450 g of water?
- **a.** 0.029 molal
- **b.** 29 molal
- **c.** 0.11 molal
- **d.** 1.1×10^{-4} molal

_____ **24.** The mole fraction of ethanol in a solution containing 1.50 moles of ethanol and 3.25 mol of water is:
- **a.** 0.316
- **b.** 0.217
- **c.** 0.462
- **d.** 0.681

_____ **25.** The addition of antifreeze to water in a car radiator causes the freezing point of the mixture to:
- **a.** increase.
- **b.** decrease.
- **c.** remain the same.
- **d.** vary unpredictably.

_____ **26.** What is the molality of an aqueous solution of a molecular solute if the boiling point of the solution is 101.4 °C?
- **a.** 2.70 molal
- **b.** 0.515 molal
- **c.** 1.04 molal
- **d.** 0.556 molal

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true NT.

_____ **27.** Whether a solute dissolves in a given solvent is determined by the nature of the two substances.

_____ **28.** Stirring a solution at constant temperature increases the amount of solute that can be dissolved.

_____ **29.** At constant temperature, more powdered sugar will dissolve in a cup of coffee than will sugar that is in the form of cubes.

_____ **30.** Oil and water are completely miscible.

_____ **31.** Increasing the temperature increases the solubility of a given substance.

_____ **32.** A 2.5*M* solution of KNO_3 contains 2.5 moles solute particles per 1 kg of solvent.

_____ **33.** The number of moles of solute in a given solution decreases as the solution is diluted.

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_____ **34.** A solution has a lower vapor pressure than that of the solvent contained within it.

_____ **35.** The boiling point of a solution is lower than that of the pure solvent.

_____ **36.** The freezing point of a 1.0 molal solution of $MgCl_2$ is 5.58 °C lower than that of pure water.

D. Problems

Solve the following problems in the space provided. Show your work.

37. If a saturated solution of $AgNO_3$ at 20 °C contains 216 g $AgNO_3$ per 100.0 g of water, what mass of water could contain 725 g of this solute at the same temperature?

38. At 10 °C, the solubility of a gas in water is 2.45 g/L at 0.750 atm. What pressure would be required to produce an aqueous solution containing 6.25 g/L of this gas at 10 °C?

39. Calculate the molarity of a solution that contains 50.0 g of $Mg(NO_3)_2$ per 225 mL of solution.

40. What mass of $AgNO_3$ would be required to prepare a 0.250 molal solution in 125 g of water?

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E. Essay

Wrtie a short essay for the following

41. Often during the winter, salt is sprinkled on bridges and sidewalks. Explain the purpose for doing so and the reasons why salt is effective for this purpose.

F. Additional Problems

Solve the following problems in the space provided. Show your work.

42. What mass of H_2SO_4 would be required to prepare 750 mL of a 0.15*M* H_2SO_4 solution?

43. Determine the freezing point of a solution made by adding 27.5 g of methanol (CH_3OH) to 250.0 g of water.

44. What is the boiling point of an aqueous solution that contains 62.5 g of $Ba(NO_3)_2$ in 750.0 g of water?

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45. Ether has a molal freezing point constant of 1.79 °C/*m*. When 31.8 g of an unknown molecular solute is dissolved in 1110 g of ether, the resulting solution has a freezing point depression of 0.570 °C. What is the molecular mass of the solute?