Concentrations of Solutions
1. How many grams of potassium dichromate, K₂Cr₂O₇, are required to prepare 465 mL of 0.3550 M K₂Cr₂O₇ solution? How many mL of a 0.750 M K₂Cr₂O₇ stock solution would be required to prepare the same solution? Ans. 48.6 g, 220. mL

2. How many grams of barium hydroxide are required to prepare 1.00 L of 0.750 M barium hydroxide solution? How many mL of a 6.00 M barium hydroxide stock solution would be required to prepare the same solution? Ans. 128 g, 125 mL

3. A solution is prepared by diluting 225 mL of 0.1885 M aluminum sulfate solution with water to a final volume of 1.450 L. Calculate
   a. the number of moles of aluminum sulfate before dilution. Ans. 0.0424 mol
   b. the molarities of the aluminum sulfate, aluminum ions, and sulfate ions in the diluted solution. Ans. [Al₂(SO₄)₃] = 0.0293 M, [Al³⁺] = 0.0584 M, [SO₄²⁻] = 0.0876 M

4. A solution is prepared by diluting 0.7850L of 1.262 M potassium sulfide solution with water to a final volume of 2.000 L.
   a. How many grams of potassium sulfide were dissolved to give the original solution? Ans. 109.3 g
   b. What are the molarities of the potassium sulfide, potassium ions, and sulfide ion in the diluted solution? Ans. [K₂S] = 0.4953M, [S²⁻] = 0.4953, [K⁺] 0.9906M

5. Answer the following questions concerning solutions of barium perchlorate, Ba(ClO₄)₂.
   a. What mass of Ba(ClO₄)₂ is required to prepare 1.370 L of a 0.08415 M solution of Ba(ClO₄)₂? Ans. 38.76 g
   b. What volume of a 0.0579 M Ba(ClO₄)₂ solution is needed to provide 12.01 g of Ba(ClO₄)₂? Ans. 617 mL
   c. What is the molarity of a 2.750 L solution containing 26.44 g of Ba(ClO₄)₂? Ans. 0.02860 M

6. Answer the following questions concerning solutions of copper (II) sulfate.
   a. What is the molarity of a 478 mL solution containing 12.50 g of copper (II) sulfate? Ans. 0.164 M
   b. What mass of copper (II) sulfate is required to prepare 283 mL of a 0.299 M copper (II) sulfate solution? Ans. 13.5 g
   c. What volume of a 0.8415 M copper (II) sulfate solution is needed to provide 4.163 g of copper (II) sulfate? Ans. 30.99 mL

7. A solution is prepared by dissolving 12.15 g of nickel (II) nitrate (182.7 g/mol) in 175 g of water.
   a. Calculate the mass percent of nickel (II) nitrate. Ans. 6.49 %
   b. Calculate the ppm of nickel (II) nitrate. Ans. 6.49 x 10⁴ ppm
   c. Calculate the mole fraction of nickel ions. Ans. 0.00670

8. Acetone, C₃H₆O, is the main ingredient of nail polish remover. A solution is made up by adding 35.0 mL of acetone (d = 0.790 g/mL) to 50.0 mL of ethyl alcohol, C₂H₆O (d = 0.789 g / mL). Assume the volumes are additive.
   a. Calculate the mass percent of acetone. Ans. 41.2 %
   b. Calculate the ppm of acetone. Ans. 4.12 x 10⁵ ppm
   c. Calculate the volume percent of ethyl alcohol. Ans. 58.8 %
   d. Calculate the mole fraction of acetone. Ans. 0.357
9. Answer the following questions concerning solutions of potassium hydroxide.
   a. A 1.13 M solution of potassium hydroxide has a density of 1.05 g/mL. What is the molality and mass percent of the solute? Ans. 1.14 m, 6.04 %
   b. A 30.0 mass percent solution has a density of 1.29 g/mL. What is the molarity and the molality? Ans. 6.90 M, 7.64 m
   c. A 14.2 m solution has a density of 1.43 g/mL. What is the molarity and mass percent? Ans. 11.3 M, 44.4 %

10. Answer the following questions concerning solutions of ammonium sulfate.
   a. A 0.886 M solution of ammonium sulfate has a density of 1.06 g/mL. What is the molality and mass percent of the solute? Ans. 0.939 m, 11.0 %
   b. A 26.0 mass percent solution has a density of 1.15 g/mL. What is the molarity and the molality? Ans. 2.27 M, 2.66 m
   c. A 3.11 m solution has a density of 1.23 g/mL. What is the molarity and mass percent? Ans. 2.71 M, 29.1 %

Predicting Solubilities (answers at the end of this section)

11. Which of the following is more likely to be soluble in benzene (C₆H₆)?
   a. CCl₄ or NaCl
   b. hexane (C₆H₁₄) or glycerol (CH₂OHCHOHCH₂OH)
   c. acetic acid (CH₃COOH) or heptanoic acid (C₇H₁₄COOH)

12. Which of the following is more soluble in CCl₄?
   a. hexane (C₆H₁₄) or CaCl₂
   b. benzene (C₆H₆) or ethyl alcohol (C₂H₅OH)
   c. I₂ or NaI

13. Choose the member of each set that would be more soluble in water?
   a. naphthalene (C₁₀H₈) or hydrogen peroxide H-O-O-H
   b. CaCO₃ or NaOH
   c. methyl alcohol (CH₃OH) or methyl ether (CH₃-O-CH₃)
   d. methane (CH₄) or KI
   e. ammonia (NH₃) or CH₄
   f. K₂SO₄ or CaSO₄

   Answers
   11a. CCl₄   b. hexane   c. heptanoic acid
   12a. hexane   b. benzene   c. I₂

Solubilities and Henry's Law

14. The Henry's law constant for the solubility of helium in water is 3.8 x 10⁻⁴ M/atm at 25°C.
   a. If the partial pressure of He at 25°C is 0.389 atm, what is the concentration of dissolved He in mol/L at 25°C? Ans. 1.5 x 10⁻⁴ M
   b. What volume of helium gas can be dissolved in 10.00L of water at 0.389 atm and 25°C. Ans. 95mL
15. The Henry's law constant for the solubility of argon in water is $1.0 \times 10^{-3}$ M/atm at 30°C.
   a. If the partial pressure of Ar at 30°C is 0.912 atm, what is the concentration of dissolved Ar in M at 30°C? Ans. $9.1 \times 10^{-4}$ M
   b. How many grams of argon gas can be dissolved in 25 L of water at 0.912 atm and 30°C? Ans. 0.91 g

16. A carbonated beverage is made by saturating water with CO$_2$ at 0°C and a pressure of 3.0 atm. The bottle is then opened at room temperature (25°C), and comes to equilibrium with air in a room where the P$_{CO_2} = 3.4 \times 10^{-4}$ atm. The Henry's law constant for the solubility of CO$_2$ in water is 0.0769 M/atm at 0°C and 0.0313 M/atm at 25°C.
   a. What is the concentration of CO$_2$ in the bottle before it is opened? Ans. 0.23 M
   b. What is the concentration of CO$_2$ in the bottle after it is opened and is at equilibrium with the air? Ans. $1.1 \times 10^{-5}$ M
   c. If the CO$_2$ given off by 2 L of a carbonated beverage were collected and stored at 1 atm and 25°C what volume would it occupy? Ans. 11 L

17. The Henry's law constant for the solubility of oxygen in water is $3.30 \times 10^{-4}$ M/atm at 12°C. Air is 21 mol% oxygen. How many grams of oxygen can be dissolved in one liter of a trout stream at 12°C (54°F) at an air pressure of 1.00 atm? Ans. 0.0022 g

Colligative Properties

18. Using the equation $\Delta P_1 = X_2 P_1^0$, calculate the vapor pressure of water over each of the following ethylene glycol (C$_2$H$_6$O$_2$) solutions at 22°C (vp of pure water = 19.83 mm Hg). For b and c, the mole fraction of ethylene glycol must be calculated first.
   a. $X_{C_2H_6O_2} = 0.288$ Ans. vp = 14.1 mm Hg
   b. 39.0 mass % ethylene glycol Ans. $X_{C_2H_6O_2} = 0.157$, vp = 16.7 mm Hg
   c. 2.42 m ethylene glycol Ans. $X_{C_2H_6O_2} = 0.0418$, vp = 19.00 mm Hg

19. Calculate the osmotic pressure of the following solutions of urea, (NH$_2$)$_2$CO, at 22°C.
   a. 0.217 M urea Ans. 5.26 atm
   b. 25.0 g urea dissolved in 685 mL of solution. Ans. 14.7 atm

20. Calculate the freezing point and boiling point of each of the following solutions. (K$_f$ = 1.86 °C/m  K$_b$ = 0.52 °C/m)
   a. 25.0 % by mass glycerin, C$_3$H$_8$O$_3$ in water. Ans. $T_f = -6.73$ °C, $T_b = 101.9$ °C
   b. 28.0 g of propylene glycol, C$_3$H$_8$O$_2$, in 325 mL of water (d = 1.00 g/mL). Ans. $T_f = -2.10$ °C, $T_b = 100.59$ °C

21. Calculate the freezing and boiling points of 0.25 m aqueous solutions of the following: (K$_f$ = 1.86 °C/m  K$_b$ = 0.52 °C/m)
   a. NH$_4$NO$_3$
   b. NiCl$_3$
   c. Al$_2$(SO$_4$)$_3$
   Ans. a. $T_f = -0.93$ °C, $T_b = 100.26$ °C b. $T_f = -1.9$ °C, $T_b = 100.52$ °C c. $T_f = -2.3$, $T_b = 100.65$ °C
22. Arrange 0.30 m solutions of the following solutes in order of increasing freezing point and boiling point.
   Fe(NO$_3$)$_3$, C$_2$H$_5$OH, Ba(OH)$_2$, CuSO$_4$

   Ans. F.P.   Fe(NO$_3$)$_3$ < Ba(OH)$_2$ < CuSO$_4$ < C$_2$H$_5$OH
   B.P.   C$_2$H$_5$OH < CuSO$_4$ < Ba(OH)$_2$ < Fe(NO$_3$)$_3$

Colligative Properties and Molar Mass

23. The Rast method uses camphor (C$_{10}$H$_{16}$O) as a solvent for determining the molar mass of a compound. When 2.50 g of cortisone acetate is dissolved in 50.00 g of camphor (K$_f$ = 40.0$^\circ$C/m), the freezing point of the mixture is 173.44$^\circ$C. The freezing point of pure camphor is 178.40$^\circ$C. What is the molar mass of cortisone acetate?  
   Ans. 403 g/mol

24. An organic compound has an empirical formula of C$_3$H$_2$NO$_2$. 3.16 g of this compound is dissolved in 75.0 mL of cyclohexane (d = 0.779 g/mL, K$_f$ = 20.2$^\circ$C/m). The solution has a freezing point of 0.0$^\circ$C. The freezing point of pure cyclohexane is 6.50$^\circ$C. What is the molar mass and molecular formula for the compound?  
   Ans. 168 g/mol, C$_6$H$_4$N$_2$O$_4$

25. Lauryl alcohol is obtained from the coconut and is an ingredient in many hair shampoos. Its empirical formula is C$_{12}$H$_{26}$O. A solution of 5.00 g of lauryl alcohol in 100.0 g of benzene (K$_b$ = 2.53$^\circ$C/m) boils at 80.78$^\circ$C. The boiling point for pure benzene is 80.10$^\circ$C. What is the molar mass and molecular formula for lauryl alcohol?  
   Ans. 186 g/mol C$_{12}$H$_{26}$O

26. A biochemist isolates a new protein and determines its molar mass by osmotic pressure measurements. A 50.0 mL solution is prepared by dissolving 225 mg of protein in water. The solution has an osmotic pressure of 4.18 mm Hg at 25 $^\circ$C. What is the molar mass of the new protein?  
   Ans. 2.00 x $10^4$ g/mol

27. The molar mass of a type of hemoglobin was determined by osmotic pressure measurement. A student measured an osmotic pressure of 4.60 mm Hg for a solution at 20$^\circ$C containing 3.27 g of hemoglobin in 0.200 L of solution. What is the molar mass of the hemoglobin?  
   Ans. 6.50 x $10^4$ g/mol