Chem101: General Chemistry
Chapter 7 - Solutions and Coloids

Physical States of Solutions (Section 7.1)

7.1 Many solution are found in the home. Some are listed below, with the composition as printed on the label. When no percentage is indicated, components are usually given in order of decreasing amount. When water is present, it is often not mentioned on the label or it is listed as inert ingredients. Identify the solvent and solutes of the following solutions:

a) antiseptic mouthwash: alcohol 25 %, thymol, eucalyptol, methyl salicylate, menthol, benzoic acid, boric acid
b) paregoric: alcohol 45 %, opium 0.4 %
c) baby oil: mineral oil, lanolin (there happens to be no water in this solution-why?)
d) distilled vinegar: acetic acid 5 %

SOLUTION:

a) Water is implied as the solvent. The alcohol and others are solutes.
b) Water is the solvent. Alcohol and opium are the solutes.
c) Mineral oil is the solvent. Lanolin is the solute. Water is immiscible with these.
d) Water is the solvent. Acetic acid is the solute.

7.3 Classify the following as being a solution or not a solution. Explain you reasons when you classify one as not a solution. For the ones classified as solutions, identify the solvent and solute(s).

a) maple syrup b) milk c) eye drops d) tomato juice e) tap water

SOLUTION:

a) Maple syrup is a solution. It is colored but is not cloudy. Water is the solvent. Various sugars are the solutes.
b) Milk is not a solution. It is a homogenous colloid.
c) Eye drops is a solution. Water is the solvent. All other components are solutes.
d) Tomato juice is not a solution. It is not homogeneous.
e) Tap water is a solution. Water is the solvent. Other ingredients are solutes.

Solubility (Section 7.2)

7.5 Use the terms *soluble, insoluble,* or *immiscible* to describe the behavior of the following pairs of substances when shaken together:

a) 25 mL of water and 1 g of salt-the resulting mixture is clear and colorless.
b) 25 mL of water and 1 g of solid silver chloride-the resulting mixture is cloudy and the solid settles out.
c) 25 mL of water and 5 mL of mineral oil-the resulting mixture is cloudy and gradually separates into two layers.

SOLUTION:

a) soluble b) insoluble c) immiscible

7.7 Define the term miscible. It is not defined in the text.

SOLUTION:
Miscible liquids have unlimited solubility in each other. Mixtures of these liquids never separate into two phases.

7.9 Suppose you put 35.8 g of ammonium sulfate into a flask and add 100 g of water at 0 °C. After stirring to dissolve as much solute as possible, will you have a saturated or unsaturated solution? Explain your answer. See Table 7.2.

SOLUTION:
Unsaturated. According to Table 7.2, it would take 70.6 g in 100 g H_2O to be saturated.

7.11 Classify each of the following solutes into the approximate solubility categories of Table 7.3. The numbers in parentheses are the grams of solute that will dissolve in 100 g of water at the temperature indicated.
a) boric acid, H_3BO_3 (6.35 g at 30 °C)
b) calcium hydroxide, $Ca(OH)_2$ (5.35 g at 30 °C)
c) antimony(III) sulfide, Sb_2S_3 (1.75×10^{-4} g at 18 °C)
d) copper(II) chloride, $CuCl_2$ (70.6 g at 0 °C)
e) iron(II) bromide, $FeBr_2$ (109 g at 10 °C)

SOLUTION:
a) soluble b) soluble c) insoluble d) soluble e) soluble

The Solution Process (Section 7.3)

7.13 What is the difference between a nonhydrated ion and a hydrated ion? Draw a sketch using the Cl^- ion to help illustrate you answer.

SOLUTION:
The hydrated ion is the ion surrounded by water molecules, having the dipole of the water oriented to spread the ionic charge. Figure 7.4 in the text illustrates what the sketch should look like.

7.15 Ground up limestone ($CaCO_3$) is used as a gentle abrasive in some powdered cleansers. Why is this a better choice than ground up soda ash (Na_2CO_3)?

SOLUTION:
$CaCO_3$ is not soluble in water. It forms a paste when mixed with a little bit of water. The $CaCO_3$ particles in the paste can act as an abrasive. In contrast, Na_2CO_3 is soluble in water. It would dissolve and not make such a paste in water.

7.17 Indicate which of the following substances (with geometries shown in the text) would be soluble in water (a polar solvent) and in benzene (a nonpolar solvent):
a) H_2S b) HCl c) H_2O_2 d) N_2

SOLUTION:
a) H_2S is a polar molecule. It is soluble in water and insoluble in benzene.
b) HCl is a polar molecule. It is soluble in water and insoluble in benzene.
c) H_2O_2 is a polar molecule. It is soluble in water and insoluble in benzene.
d) N_2 is a nonpolar molecule. It is insoluble in water and soluble in benzene.

7.19 Suppose you put a piece of a water soluble solid into a beaker that contains water and stir the mixture briefly. You find that the solid does not immediately dissolve completely. Describe three things you might do to try to get the solid to dissolve.

SOLUTION:
A solid would dissolve faster (1) at a higher temperature; (2) if the solid were crushed into smaller particles; or (3) if the solution were stirred.

Solution Concentrations (Section 7.4)

7.21 Calculate the molarity of the following solutions:
a) 2.00 L of solution contains 0.860 mol of solute
b) 500 mL of solution contains 0.304 mol of solute
c) 0.115 mol of solute is put into a container and enough distilled water is added to give 250 mL of solution

SOLUTION:

a) $M = \frac{0.860 \text{ mol solute}}{2.00 \text{ L of soln}} = 0.430 \text{ M}$

b) $M = \frac{0.304 \text{ mol solute}}{0.500 \text{ L of soln}} = 0.608 \text{ M}$

c) $M = \frac{0.115 \text{ mol solute}}{0.250 \text{ mL of soln}} = 0.460 \text{ M}$

7.23 Calculate the molarity of the following solutions:
a) A sample of solid Na_2SO_4 weighing 0.140 g is dissolved in enough water to make 10.0 mL of solution.
b) A 4.50 g sample of glucose ($C_6H_{12}O_6$) is dissolved in enough water to give 150 mL of solution.
c) A 43.5 g sample of K_2SO_4 is dissolved in a quantity of water, and the solution is stirred well. A 25.0 mL sample of the resulting solution is evaporated to dryness and leaves behind 2.18 g of solid K_2SO_4.

SOLUTION:

a) $M = \frac{0.140 \cancel{\text{g } Na_2SO_4} \times \frac{1 \text{ mol } Na_2SO_4}{142 \cancel{\text{g } Na_2SO_4}}}{0.0100 \text{ L soln}} = 0.0986 \text{ M}$

b) $M = \frac{4.50 \cancel{\text{g } C_6H_{12}O_6} \times \frac{1 \text{ mol } C_6H_{12}O_6}{180 \cancel{\text{g } C_6H_{12}O_6}}}{0.150 \text{ L soln}} = 0.167 \text{ M}$

c) Use the data that give a relationship between the volume and the mass of the same sample.

$M = \frac{2.18 \cancel{\text{g } K_2SO_4} \times \frac{1 \text{ mol } K_2SO_4}{174.3 \cancel{\text{g } K_2SO_4}}}{0.025 \text{ L soln}} = 0.500 \text{ M}$

7.25 Calculate the quantity asked for.
a) How many moles of solute is contained in 1.25 L of a 0.350 M solution?
b) How many moles of solute is contained in 200 mL of a 0.750 M solution?
c) What volume of a 0.415 M solution contains 0.500 mol of solute?

SOLUTION:
a) mol solute = M x L soln = 0.350 mol solute/$\cancel{\text{L soln}}$ x 1.25 $\cancel{\text{L soln}}$ = 0.438 mol solute
b) mol solute = M x L soln = 0.750 mol solute/$\cancel{\text{L soln}}$ x 0.200 $\cancel{\text{L soln}}$ = 0.150 mol solute

c) $\text{L soln} = \dfrac{\text{mol solute}}{\text{M}} = \dfrac{0.500\ \cancel{\text{mol solute}}}{0.415\ \cancel{\text{mol solute}}/\text{L soln}} = 1.20\ \text{L soln}$

7.27 Calculate the quantity asked for.

a) How many grams of solid $AgNO_3$ will be needed to prepare 200 mL of 0.200 M solution?

b) How many grams of vitamin C ($C_6H_8O_6$) would be contained in a 25.0 mL of 1.00 M solution?

c) How many moles of HCl is contained in 250 mL of 6.0 M solution?

SOLUTION:

a) $\text{mol solute} = 0.200\ \text{mol AgNO}_3/\cancel{\text{L soln}} \times 0.200\ \cancel{\text{L soln}} = 0.0400\ \text{mol AgNO}_3$

$\text{g solute} = 0.0400\ \cancel{\text{mol AgNO}_3} \times \dfrac{169.9\ \text{g AgNO}_3}{\cancel{\text{mol AgNO}_3}} = 6.80\ \text{g AgNO}_3$

b) $\dfrac{1.00\ \text{mol C}_6\text{H}_8\text{O}_6}{\cancel{\text{L soln}}} \times 0.025\ \cancel{\text{L soln}} = 0.0250\ \text{mol C}_6\text{H}_8\text{O}_6$

$0.0250\ \cancel{\text{mol C}_6\text{H}_8\text{O}_6} \times \dfrac{176\ \text{g C}_6\text{H}_8\text{O}_6}{\cancel{\text{mol C}_6\text{H}_8\text{O}_6}} = 4.4\ \text{g C}_6\text{H}_8\text{O}_6$

c) $\dfrac{6.0\ \text{mol HCl}}{\cancel{\text{L soln}}} \times 0.250\ \cancel{\text{L soln}} = 1.5\ \text{mol HCl}$

7.29 Calculate the concentration in % (w/w) of the following solutions. Assume water has a density of 1.00 g/mL.

a) 7.5 g of table salt and 100 mL of water

b) 7.5 g of any solute and 100 mL of water

c) 7.5 g of any solute and 100 g of any solvent

SOLUTION:

$\%\ (\text{w/w}) = \dfrac{\text{weight of solute}}{\text{weight of soln}} \times 100$

a) $\dfrac{7.5\ \text{g NaCl}}{100\ \text{mL} \times 1.00\ \text{g/mL} + 7.5\ \text{g}} \times 100 = 7.0\ \%\ (\text{w/w})\ \text{NaCl}$

b) $\dfrac{7.5\ \text{g solute}}{107.5\ \text{g soln}} \times 100 = 7.0\ \%\ (\text{w/w})\ \text{solute}$

c) $\dfrac{7.5\ \text{g solute}}{107.5\ \text{g soln}} \times 100 = 7.0\ \%\ (\text{w/w})$

7.31 Calculate the concentration in % (w/w) of the following solutions. Assume water has a density of 1.00 g/mL.

a) 5.20 g of $CaCl_2$ is dissolved in 125 mL of water

b) 0.200 mol of solid KBr is dissolved in 200 mL of water

c) 50.0 g of solid is dissolved in 250 mL of water

d) 10.0 mL of ethyl alcohol (density = 0.789 g/mL) is mixed with 10.0 mL of ethylene glycol (density = 1.11 g/mL).

SOLUTION:

a) $\%\ (\text{w/w}) = \dfrac{5.20\ \text{g CaCl}_2}{125\ \text{g H}_2\text{O} + 5.20\ \text{g CaCl}_2} \times 100 = 4.00\ \%\ (\text{w/w})\ \text{CaCl}_2$

b) $$\% \text{ (w/w)} = \frac{0.200 \cancel{\text{mol KBr}} \times 119 \text{ g KBr}/\cancel{\text{mol KBr}}}{200 \text{ g } H_2O + (0.200 \times 119) \text{ g KBr}} \times 100 = 10.6 \% \text{ (w/w) KBr}$$

c) $$\% \text{ (w/w)} = \frac{50.0 \text{ g solid}}{250 \text{ g } H_2O + 50.0 \text{ g solid}} \times 100 = 16.7 \% \text{ (w/w)}$$

d) wt alcohol = 10.0 $\cancel{\text{mL}}$ x 0.789 g/$\cancel{\text{mL}}$ = 7.89 g alcohol
wt ethylene glycol = 10.0 $\cancel{\text{mL}}$ x 1.11 g/$\cancel{\text{mL}}$ = 11.1 g ethylene glycol
wt soln = 11.1 g ethylene glycol + 7.89 g alcohol = 19.0 g soln

$$\% \text{ (w/w)} = \frac{7.89 \text{ g alcohol}}{19.0 \text{ g soln}} \times 100 = 41.5 \% \text{ (w/w) alcohol}$$

7.33 Calculate the concentration in % (w/w) of the following solutions:
a) 424 g of solute is dissolved in water to give 1.00 L of solution. The density of the resulting solution is 1.18 g/mL
b) A 50.0 mL solution sample with a density of 0.898 g/mL leaves 12.6 g of solid residue when evaporated
c) A 25.0 g sample of solution upon evaporation leaves a 2.32 g residue of NH_4Cl

SOLUTION:

a) wt soln = 1.00 $\cancel{\text{L}}$ x 1000 $\cancel{\text{mL}}/\cancel{\text{L}}$ x 1.18 g/$\cancel{\text{mL}}$ = 1180 g soln

$$\% \text{ (w/w)} = \frac{424 \text{ g solute}}{1180 \text{ g soln}} \times 100 = 35.9 \% \text{ (w/w)}$$

b) wt soln = 50.0 $\cancel{\text{mL soln}}$ x 0.898 g soln/$\cancel{\text{mL soln}}$ = 44.9 g soln

$$\% \text{ (w/w)} = \frac{12.6 \text{ g solute}}{44.9 \text{ g soln}} \times 100 = 28.1 \% \text{ (w/w)}$$

c) $$\% \text{ (w/w)} = \frac{2.32 \text{ g solute}}{25.0 \text{ g soln}} \times 100 = 9.28 \% \text{ (w/w)}$$

7.35 Calculate the concentration in % (v/v) of the following solutions:
a) 250 mL of solution contains 20.0 mL of acetone.
b) 250 mL of solution contains 20.0 mL of any soluble liquid solute
c) 1.0 quart of acetic acid is put into a 5 gallon container, and enough water is added to fill the container
d) A solution of acetone and water is separated by distillation. A 300 mL sample gives 109 mL of acetone.

SOLUTION:

a) $$\% \text{ (v/v)} = \frac{20.0 \text{ mL acetone}}{250 \text{ mL soln}} \times 100 = 8.00 \% \text{ acetone (v/v)}$$

b) $$\% \text{ (v/v)} = \frac{20.0 \text{ mL solute}}{250 \text{ mL soln}} \times 100 = 8.00 \% \text{ (v/v)}$$

c) $$\% \text{ (v/v)} = \frac{1.0 \text{ qt acetic acid}}{5 \text{ gal soln} \times 4 \text{ qts/gal}} \times 100 = 5 \% \text{ acetic acid (v/v)}$$

d) $$\% \text{ (v/v)} = \frac{109 \text{ mL acetone}}{300 \text{ mL soln}} \times 100 = 36.3 \% \text{ acetone (v/v)}$$

7.37 The blood serum acetone level for a person is determined to be 1.8 mg of acetone per 100 mL of serum. Express this concentration as % (v/v) if liquid acetone has a density of 0.79 g/mL.

SOLUTION:

$$\frac{1.8 \cancel{\text{ mg acetone}}}{100 \text{ mL blood}} \times \frac{1 \cancel{\text{ g acetone}}}{1000 \cancel{\text{ mg acetone}}} \times \frac{1 \text{ mL acetone}}{0.79 \cancel{\text{ g acetone}}} \times 100 = 0.0023 \% \text{ acetone (v/v)}$$

7.39 Calculate the concentration in % (w/v) of the following solutions:

a) 28.0 g of solute is dissolved in 200 mL of water to give a solution with a density of 1.10 g/mL

b) A 25.0 mL solution sample upon evaporation leaves a solid residue of 0.38 g.

c) Upon analysis for total protein, a blood serum sample of 15.0 mL is found to contain 1.02 g of total protein..

SOLUTION:

a) weight of soln $= 28.0 \text{ g solute} + 200 \cancel{\text{ mL } H_2O} \times 1.00 \text{ g } H_2O/\cancel{\text{mL } H_2O} = 228 \text{ g soln}$

$$\text{volume of soln} = \frac{228 \cancel{\text{ g soln}}}{1.10 \cancel{\text{ g soln}}\text{/mL soln}} = 207 \text{ mL soln}$$

$$\% \text{ (w/v)} = \frac{28.0 \text{ g solute}}{207 \text{ mL soln}} \times 100 = 13.5 \% \text{ (w/v)}$$

b) $$\% \text{ (w/v)} = \frac{0.38 \text{ g solute}}{25.0 \text{ mL soln}} \times 100 = 1.52 \% \text{ (w/v)}$$

c) $$\% \text{ (w/v)} = \frac{1.02 \text{ g protein}}{15.0 \text{ mL soln}} \times 100 = 6.80 \% \text{ protein (w/v)}$$

7.41 Assume the density of the solution prepared in Exercise 7.40 is 1.18 g/mL and express the concentration in % (w/v).

SOLUTION:

From Figure 7.3, the solubility of KCl is about 30 g/100 g H_2O

weight of soln $= 30 \text{ g KCl} + 100 \text{ g } H_2O = 130 \text{ g soln}$

$$\text{volume of soln} = \frac{130 \cancel{\text{ g soln}}}{1.18 \cancel{\text{ g soln}}\text{/mL soln}} = 110 \text{ mL soln}$$

$$\% \text{ (w/v)} = \frac{30 \text{ g KCl}}{110 \text{ mL soln}} \times 100 = 27 \% \text{ KCl (w/v)}$$

Solution Preparation (Section 7.5)

7.43 Explain how you would prepare the following solutions using pure solute and water. Assume water has a density of 1.00 g/mL.

a) 500 mL of 2.00 M NaOH solution

b) 250 mL of 40.0 % (v/v) alcohol solution (C_2H_5OH)

c) 100 mL of 10.0 % (w/v) glycerol solution. Glycerol is a liquid with a density of 1.26 g/mL. Describe two ways to measure out the amount of glycerol needed.

d) approximately 100 mL of normal saline solution, 0.89 % (w/w) NaCl

SOLUTION:

a) mol NaOH = 2.00 mol NaOH/~~L soln~~ x 0.500 ~~L soln~~ = 1.00 mol NaOH
g NaOH = 1.00 ~~mol NaOH~~ x 40.0 g NaOH/~~mol NaOH~~ = 40.0 g NaOH
Dissolve 40.0 g NaOH in enough water to make 500 mL solution.

b) $$\text{mL alcohol} = \frac{\%\ (v/v)\ x\ \text{mL soln}}{100} = \frac{40.0\ \%\ x\ 250\ \text{mL soln}}{100} = 100\ \text{mL alcohol}$$

Dissolve 100 mL alcohol in enough water to give 250 mL solution.
Note: You cannot make it by mixing 100 mL alcohol and 150 mL water. The total volume is not the sum of the volumes of the two liquids.

c) $$\text{g glycerol} = \frac{\%\ (w/v)\ x\ \text{mL soln}}{100} = \frac{10.0\ \%\ x\ 100\ \text{mL soln}}{100} = 10.0\ \text{g glycerol}$$

$$\text{volume glycerol} = \frac{10.0\ \cancel{\text{g glycerol}}}{1.26\ \cancel{\text{g glycerol}}/\text{mL}} = 7.94\ \text{mL glycerol}$$

Weigh out 10.0 g glycerol or measure 7.94 mL glycerol, and dissolve in enough water to make 100 mL of solution.

d) Assuming the solution has a density of approximately 1.00 g/mL, the 100 mL (approx) weighs approximately 100 g.

$$\text{wt NaCl} = \frac{\%\ (w/w)\ x\ \text{wt soln}}{100} = \frac{0.89\ \%\ x\ 100\ \text{g}}{100} = 0.89\ \text{g NaCl}$$

Dissolve 0.89 g NaCl in slightly less than 100 mL (approx. 99 mL) of water.

7.45 Calculate the following:

a) The number of moles of NaI in 50.0 mL of 0.400 M solution.
b) The number of grams of KBr in 120 mL of 0.720 M solution.
c) The number of grams of NaCl in 20.0 mL of 1.20 % (w/v) NaCl solution.
d) The number of millimeters of alcohol in 250 mL of 20.0 % (v/v) solution.

SOLUTION:

a) mol NaI = 0.400 mol NaI/~~L soln~~ x 0.0500 ~~L soln~~ = 0.020 mol NaI
b) mol KBr = 0.720 mol KBr/~~L soln~~ x 0.120 ~~L soln~~ = 0.0864 mol KBr
g KBr = 0.0864 ~~mol KBr~~ x 119 g KBr/~~mol KBr~~ = 10.3 g KBr

c) $$\text{g NaCl} = \frac{1.2\ \%\ (w/v)\ x\ 20.0\ \text{mL soln}}{100} = 0.24\ \text{g NaCl}$$

d) $$\text{mL alcohol} = \frac{20.0\ \%\ (v/v)\ x\ 250\ \text{mL}}{100} = 50.0\ \text{mL alcohol}$$

7.47 Explain how you would prepare the following dilute solutions from the more concentrated ones:

a) 200 mL of 0.500 M HCl from 6.00 M HCl solution
b) 50.0 mL of 2.00 M H_2SO_4 from 6.00 M H_2SO_4 solution
c) 100 mL of normal saline solution, 0.89 % (w/v) NaCl, from 5.0 % (w/v) NaCl
d) 250 mL of 5.00 % (v/v) acetone from 20.5 % (v/v) acetone

SOLUTION:

Use Equation 7.9: $C_c\ x\ V_c = C_d\ x\ V_d$, where C can be M, % (w/v), or % (v/v).

$$V_c = \frac{C_d\ x\ V_d}{C_c}$$

a) $$V_c = \frac{0.500\ \cancel{M}\ x\ 200\ \text{mL}}{6.00\ \cancel{M}} = 16.7\ \text{mL}$$

Take 16.7 mL of 6.00 M HCl and add enough water to make 200 mL.

b) $V_c = \frac{2.00\ \cancel{M} \times 50.0\ mL}{6.00\ \cancel{M}} = 16.7\ mL$

Take 16.7 mL of 6.00 M H_2SO_4. Add it to enough water to make 50.0 mL solution.

c) $V_c = \frac{0.89\ \cancel{\%\ (w/v)} \times 100\ mL}{5.00\ \cancel{\%\ (w/v)}} = 17.8\ mL$

Add 17.8 mL of 5.0 % NaCl (w/v) to enough water to make 100 mL solution.

d) $V_c = \frac{5.00\ \cancel{\%\ (v/v)} \times 250.0\ mL}{20.5\ \cancel{\%\ (v/v)}} = 61.0\ mL$

Add 61.0 mL of 20.5 % (v/v) acetone to enough water to make 250 mL solution.

7.49 What is the molarity of the solution prepared by diluting 25.0 mL of 0.412 M $Mg(NO_3)_2$ to each of the following final volumes?

a) 50.0 mL b) 120 mL c) 1.50 L d) 475 mL

SOLUTION:

Rearrange Equation 7.9 to get: $M_d = \frac{M_c \times V_c}{V_d}$

a) $M_d = \frac{0.412\ M \times 25.0\ mL}{50.0\ mL} = 0.206\ M$

b) $M_d = \frac{0.412\ M \times 25.0\ mL}{120\ mL} = 0.0858\ M$

c) $M_d = \frac{0.412\ M \times 25.0\ mL}{1500\ mL} = 0.00687\ M$

d) $M_d = \frac{0.412\ M \times 25.0\ mL}{475\ mL} = 0.0217\ M$

Solution Stoichiometry (Section 7.6)

7.51 How many mL of 6.00 M HCl solution would be needed to react exactly with 25.0 g of pure solid NaOH?

$HCl(aq) + NaOH(s) \rightarrow NaCl(aq) + H_2O(l)$

SOLUTION:

$$25.0\ \cancel{g\ NaOH} \times \frac{1\ \cancel{mol\ NaOH}}{40.0\ \cancel{g\ NaOH}} \times \frac{1\ \cancel{mol\ HCl}}{1\ \cancel{mol\ NaOH}} \times \frac{1\ \cancel{L\ soln}}{6.00\ \cancel{mol\ HCl}} \times \frac{1000\ mL}{1\ \cancel{L\ soln}} = 104\ mL\ soln$$

7.53 How many mL of 0.250 M HCl would be needed to react exactly with 10.5 g of solid $NaHCO_3$?

$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

SOLUTION:

$$10.5\ \cancel{g\ NaHCO_3} \times \frac{1\ \cancel{mol\ NaHCO_3}}{84.0\ \cancel{g\ NaHCO_3}} \times \frac{1\ \cancel{mol\ HCl}}{1\ \cancel{mol\ NaHCO_3}} \times \frac{1\ \cancel{L\ soln}}{0.250\ \cancel{mol\ HCl}} \times \frac{1000\ mL}{1\ \cancel{L\ soln}} = 500\ mL\ soln$$

7.55 How many mL of 0.115 M Na_2S solution will exactly react with 35.0 mL of 0.150 M $AgNO_3$ solution?

$2AgNO_3(aq) + Na_2S(aq) \rightarrow Ag_2S(s) + 2NaNO_3(aq)$

SOLUTION:

$$35.0\ \cancel{mL} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{0.150\ \cancel{mol\ AgNO_3}}{1\ \cancel{L}} \times \frac{1\ \cancel{mol\ Na_2S}}{2\ \cancel{mol\ AgNO_3}} \times \frac{1\ \cancel{L\ soln}}{0.115\ \cancel{mol\ Na_2S}} \times \frac{1000\ mL}{1\ \cancel{L\ soln}} = 22.8\ mL\ Na_2S$$

7.57 How many mL of 0.108 M NaOH solution will exactly react with 25.0 mL of 0.125 M HCl solution?

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

SOLUTION:

$$25.0\ \cancel{mL} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{0.125\ \cancel{mol\ HCl}}{1\ \cancel{L}} \times \frac{1\ \cancel{mol\ NaOH}}{1\ \cancel{mol\ HCl}} \times \frac{1\ \cancel{L\ soln}}{0.108\ \cancel{mol\ NaOH}} \times \frac{1000\ mL}{1\ \cancel{L\ soln}} = 28.9\ mL\ Na_2S$$

7.59 How many mL of 0.108 M NaOH solution will exactly react with 25.0 mL of 0.125 M H_3PO_4 solution?

$3NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$

SOLUTION:

$$25.0\ \cancel{mL} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{0.125\ \cancel{mol\ H_3PO_4}}{1\ \cancel{L}} \times \frac{3\ \cancel{mol\ NaOH}}{1\ \cancel{mol\ H_3PO_4}} \times \frac{1\ \cancel{L\ soln}}{0.108\ \cancel{mol\ NaOH}} \times \frac{1000\ mL}{1\ \cancel{L\ soln}} = 86.8\ mL\ NaOH$$

7.61 An ingredient found in some antacids is magnesium hydroxide, $Mg(OH)_2$. Calculate the number of grams of $Mg(OH)_2$ needed to react exactly with 250 mL of stomach acid (see Exercise 7.60).

$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$

SOLUTION:

$$250\ \cancel{mL} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{0.10\ \cancel{mol\ HCl}}{1\ \cancel{L}} \times \frac{1\ \cancel{mol\ Mg(OH)_2}}{2\ \cancel{mol\ HCl}} \times \frac{58.3\ g\ Mg(OH)_2}{1\ \cancel{mol\ Mg(OH)_2}} = 0.73\ g\ Mg(OH)_2$$

Solution Properties (Section 7.7)

7.63 If you look at the labels of automotive products used to prevent radiator freezing (antifreeze) and radiator boiling, you will find the same ingredient listed, ethylene glycol. Use the idea of colligative solution properties to explain how the same material can prevent an automobile cooling system from freezing and boiling.

SOLUTION:

Since pure ethylene glycol has a higher boiling than water, a solution of ethylene glycol in water has a higher boiling point than pure water. The freezing point of a solution is lower than that of pure water. Thus, the solution prevents freezing of the coolant, and can get hotter without boiling.

7.65 Calculate the boiling and freezing points of water solutions that are 1.00 M in the following solutes:

a) KBr, a strong electrolyte
b) ethylene glycol, a nonelectrolyte
c) $(NH_4)_2CO_3$, a strong electrolyte
d) $Al_2(SO_4)_3$, a strong electrolyte

SOLUTION:

Use equations 7.13 and 7.14. $M = 1.00$; $K_b = 0.52$; $K_f = 1.86$

a) For KBr, $n = 2$

$\Delta t_b = 2 \times 0.52 \times 1.00 = 1.04$ °C higher; Boiling point = 101.04 °C

$\Delta t_f = 2 \times 1.86 \times 1.00 = 3.72$ °C lower; Freezing point = −3.72 °C

b) For ethylene glycol, $n = 1$

$\Delta t_b = 1 \times 0.52 \times 1.00 = 0.52$ °C higher; Boiling point = 100.52 °C

$\Delta t_f = 1 \times 1.86 \times 1.00 = 1.86$ °C lower; Freezing point = −1.86 °C

c) For $(NH_4)_2CO_3$, $n = 3$

$\Delta t_b = 3 \times 0.52 \times 1.00 = 1.56$ °C higher; Boiling point = 101.56 °C

$\Delta t_f = 3 \times 1.86 \times 1.00 = 5.58$ °C lower; Freezing point = −5.58 °C

d) For $Al_2(SO_4)_3$, n = 5

Δt_b = 5 x 0.52 x 1.00 = 2.6 °C higher; Boiling point = 102.6 °C

Δt_f = 5 x 1.86 x 1.00 = 9.30 °C lower; Freezing point = −9.30 °C

7.67 Calculate the boiling and freezing points of the following solutions. Water is the solvent unless otherwise indicated.

a) a solution containing 50.0 g of H_2SO_4, a strong electrolyte (both H's dissociate), per 250 mL

b) a solution containing 200 g of table sugar ($C_{12}H_{22}O_{11}$), a nonelectrolyte, per 250 mL

c) a solution containing 75.0 g of octanoic acid ($C_8H_{16}O_2$), a nonelectrolyte, in enough benzene to give 250 mL of solution

SOLUTION:

Use equations 7.13 and 7.14. K_b = 0.52; K_f = 1.86 for water

a) For H_2SO_4, n = 3

$$\text{mol } H_2SO_4 = 50.0\ \cancel{g\ H_2SO_4} \times \frac{1 \text{ mol } H_2SO_4}{98.1\ \cancel{g\ H_2SO_4}} = 0.510 \text{ mol } H_2SO_4$$

$$M = \frac{0.510 \text{ mol } H_2SO_4}{0.250 \text{ L soln}} = 2.04 \text{ M}$$

Δt_b = 3 x 0.52 x 2.04 = 3.18 °C higher; Boiling point = 103.18 °C

Δt_f = 3 x 1.86 x 2.04 = 11.4 °C lower; Freezing point = −11.4 °C

b) For sucrose, n = 1

$$\text{mol } C_{12}H_{22}O_{11} = 200\ \cancel{g\ C_{12}H_{22}O_{11}} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{342\ \cancel{g\ C_{12}H_{22}O_{11}}} = 0.585 \text{ mol } C_{12}H_{22}O_{11}$$

$$M = \frac{0.585 \text{ mol } C_{12}H_{22}O_{11}}{0.250 \text{ L soln}} = 2.34 \text{ M}$$

Δt_b = 1 x 0.52 x 2.34 = 1.22 °C higher; Boiling point = 101.22 °C

Δt_f = 1 x 1.86 x 2.34 = 4.35 °C lower; Freezing point = −4.35 °C

c) For benzene, K_b = 2.53; K_f = 4.90; normal boiling point = 80.1 °C; normal freezing point = 5.5 °C

For $C_8H_{16}O_2$, n = 1

$$\text{mol } C_8H_{16}O_2 = 75.0\ \cancel{g\ C_8H_{16}O_2} \times \frac{1 \text{ mol } C_8H_{16}O_2}{144\ \cancel{g\ C_8H_{16}O_2}} = 0.521 \text{ mol } C_8H_{16}O_2$$

$$M = \frac{0.521 \text{ mol } C_8H_{16}O_2}{0.250 \text{ L soln}} = 2.08 \text{ M}$$

Δt_b = 1 x 2.53 x 2.08 = 5.26 °C higher; Boiling point = 80.1 + 5.26 = 85.4 °C

Δt_f = 1 x 4.90 x 2.08 = 10.2 °C lower; Freezing point = 5.5 − 10.2 = −4.7 °C

7.69 Calculate the osmolarity for the following solutions:

a) a 0.25 M solution of KCl, a strong electrolyte

b) a solution containing 15.0 g of urea (CH_4N_2O), a non electrolyte, per 500 mL

c) a solution containing 50.0 mL of ethylene glycol ($C_2H_6O_2$), a nonelectrolyte with a density of 1.11 g/mL per 250 mL

SOLUTION:

Osmolarity = n x M

a) For KCl, n = 2

osmolarity = 2 x 0.25 = 0.50

b) For urea, n = 1

mol urea = $15.0\ \cancel{g\ CH_4N_2O} \times \frac{1\ mol\ CH_4N_2O}{60.0\ \cancel{g\ CH_4N_2O}} = 0.25\ mol\ CH_4N_2O$

$M = \frac{0.250\ mol\ CH_4N_2O}{0.500\ L\ soln} = 0.500\ M$

osmolarity = 1 x 0.500 = 0.500

c) For ethylene glycol, n = 1

mol $C_2H_6O_2$ = $50.0\ \cancel{mL} \times \frac{1.11\ \cancel{g\ C_2H_6O_2}}{\cancel{mL}} \times \frac{1\ mol\ C_2H_6O_2}{62.0\ \cancel{g\ C_2H_6O_2}} = 0.895\ mol\ C_2H_6O_2$

$M = \frac{0.895\ mol\ C_2H_6O_2}{0.250\ L\ soln} = 3.58\ M$

osmolarity = 1 x 3.58 = 3.58

Note: In Exercises 7.71 - 7.79, assume temperature of 25.0 °C (298 K). Express answer in torr, mm Hg, and atm.

7.71 Calculate the osmotic pressure of any solution with an osmolarity of 0.250.

SOLUTION:

$\Pi = nMRT = 0.250\ \cancel{mol/L} \times 0.0821\ \cancel{L}\ atm/\cancel{mol\ K} \times 298\ \cancel{K} = 6.12\ atm$

$6.12\ \cancel{atm} \times \frac{760\ torr}{1\ \cancel{atm}} = 4.65 \times 10^3\ torr = 4.65 \times 10^3\ mm\ Hg$

7.73 Calculate the osmotic pressure of a 0.300 M solution of methanol, a nonelectrolyte.

SOLUTION:

$\Pi = nMRT = 1 \times 0.300\ \cancel{mol/L} \times 0.0821\ \cancel{L}\ atm/\cancel{mol\ K} \times 298\ K = 7.34\ atm$

$7.34\ \cancel{atm} \times \frac{760\ torr}{1\ \cancel{atm}} = 5.58 \times 10^3\ torr = 5.58 \times 10^3\ mm\ Hg$

7.75 Calculate the osmotic pressure of a solution that contains 1.20 mol of $CaCl_2$ in 1500 mL.

SOLUTION:

$\Pi = nMRT$

$n = 3;\ M = \frac{1.20\ mol\ CaCl_2}{1.500\ L\ soln} = 0.800\ M$

$\Pi = 3 \times 0.800\ \cancel{mol/L} \times 0.0821\ \cancel{L}\ atm/\cancel{mol\ K} \times 298\ \cancel{K} = 58.7\ atm$

$58.7\ \cancel{atm} \times \frac{760\ torr}{1\ \cancel{atm}} = 4.46 \times 10^4\ torr = 4.46 \times 10^4\ mm\ Hg$

7.77 Calculate the osmotic pressure of a solution that is 0.122 M in solute, and has a boiling point 0.19 °C above that of pure water.

SOLUTION:

The osmolarity of that solution can be obtained from the Δt_b.

$nM = \frac{\Delta t_b}{K_b} = \frac{0.19}{0.52} = 0.365$

$\Pi = nMRT = 0.365\ \cancel{mol/L} \times 0.0821\ \cancel{L}\ atm/\cancel{mol\ K} \times 298\ K = 8.93\ atm$

$$8.93\ \text{atm} \times \frac{760\ \text{torr}}{1\ \text{atm}} = 6.79 \times 10^3\ \text{torr} = 6.79 \times 10^3\ \text{mm Hg}$$

7.79 Calculate the osmotic pressure of a solution that contains 245.0 g of ethylene glycol ($C_2H_6O_2$), a nonelectrolyte, per liter.

SOLUTION:

Π = nMRT; For ethylene glycol, n = 1

$$\text{mol } C_2H_6O_2 = 245.0\ \text{g } C_2H_6O_2 \times \frac{1\ \text{mol } C_2H_6O_2}{62.0\ \text{g } C_2H_6O_2} = 3.95\ \text{mol } C_2H_6O_2$$

$$M = \frac{3.95\ \text{mol } C_2H_6O_2}{1\ \text{L soln}} = 3.95\ M$$

$$\Pi = 1 \times 3.95\ \text{mol/L} \times 0.0821\ \text{L atm/mol K} \times 298\ \text{K} = 96.6\ \text{atm}$$

$$96.6\ \text{atm} \times \frac{760\ \text{torr}}{1\ \text{atm}} = 7.34 \times 10^4\ \text{torr} = 7.34 \times 10^4\ \text{mm Hg}$$

Colloids and Dialysis (Section 7.8 - 7.10)

7.81 Explain why detergents or soaps are needed if water is to be used as a solvent for cleaning clothes and dishes.

SOLUTION:

The contaminant to be removed is usually a non-polar, greasy substance. Since water is a hydrogen-bonded, polar substance, grease will not dissolve in water. A soap or detergent has both a very polar part of the molecule and an extensive non-polar part. The grease is attracted to the nonpolar end of the soap and the polar end of the soap is attracted to the water, making a temporary colloid and allowing the grease to be removed along with the water.

7.83 Suppose an osmotic membrane separates a 5.0 % sugar solution from a 10.0 % sugar solution. In which direction will water flow? Which solution will become diluted as osmosis takes place?

SOLUTION:

Water flows from the solution with more water to the solution with less water, or from the 5 % sugar solution into the 10 % sugar solution. The 10 % solution will become more dilute, and the 5 % solution more concentrated.