Worksheet 9

March 8th, 2022

Collaborations are encouraged and students must report all collaborators on each assignment. All external sources (websites, books) must be cited. An *extra credit* (*EC*) problem will be available per assignment. Please submit a completed homework on-time to receive *EC* and no partial *EC* (all parts must be correct) will be given out. Additional problems are listed at the end of each assignment. This week's assignment is due *Monday, March 14th at 11:59pm.*

1. (4 pts) **Concentrations of Solutions** An car antifreeze mixture is made by mixing equal volumes of ethylene glycol (d = 1.114 g/mL, molar mass 62.07 g/mol) and deionized water (d = 1.00 g/mL) at 20.0°C. The density of the solution is 1.07 g/mL. Determine the mass percent, molarity, molality, and mole fraction of 2.00 L car antifreeze mixture. Report to 3 significant figures.

2. (2 pts) **Raoult's Law** French scientist François discovered that the vapor pressure of a solution $P(\text{solution})$ is proportional to its mole fraction x in a solution.

$$P(\text{solution}) = x(\text{solvent})P_0(\text{solvent}) \tag{1}$$

Benzene has a vapor pressure of 100.0 Torr at 26°C. A nonvolatile compound was added to 0.300 mol benzene at 26°C and the vapor pressure of the benzene in the solution decreased to 60.0 Torr. What amount (in moles) of solute molecuels were added to the benzene? Report to 3 significant figures.

3. (4 pts) **Henry's Law** The Henry's law says that the amount of dissolved gas $c(solute)$ in a given volume of solvent at equilibrium is proportional to the partial pressure of the gas $P(solute)$.

$$c(\text{solute}) = k_H P(\text{solute}) \tag{2}$$

The minimum mass concentration of oxygen O_2 required for fish life is 4.0 mg/L. Henry's constant k_H for O_2 is 1.2×10^{-3} mol/(L atm). Report results to 2 significant figures.

(a) Assume the density of lake water to be 1.00 g/mL and express this concentration in parts per million (milligrams of O_2 per kilogram of water mg/kg).

(b) What is the minimum partial pressure of O_2 that would supply the minimum mass concentration of oxygen in water to support fish life at 20.°C.

(c) What is the minimum atmospheric pressure that would give this partial pressure, assuming that oxygen exerts about 21% of the atmospheric pressure?

4. (2 pts) **Freezing Point Depression** When 1.32g of a nonpolar solute was dissolved in 50.0g of phenol, the latter's freezing point was lowered by 1.454°C. Calculate the molar mass of the solute given phenol $K_f = 7.27°\text{K}/m$. Report to 3 significant figures.

5. (2 pts) **Colligative Properties of Solution** Two beakers, one containing 0.10 m NaCl(aq) and the other containing 0.010 m $AlCl_3$(aq), are placed inside a bell jar and sealed. The beakers are left unitl the water vapor has come to equilibrium with any liquid in the container. The levels of the liquid in each beaker at the beginning of the experiment are the same, as pictured in Fig. 1. Draw the levels of the liquid in each beaker after quilibrium has been reached. Explain your reasoning.

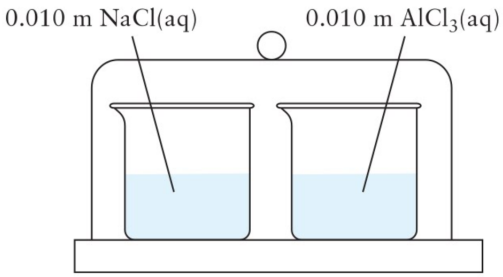

Figure 1: 0.010 m NaCl and 0.010 m $AlCl_3$ are separated in equal sized containers.

6. (3 pts) **Solid Structures** Determine the number of atoms per unit cell, see Fig. 2.

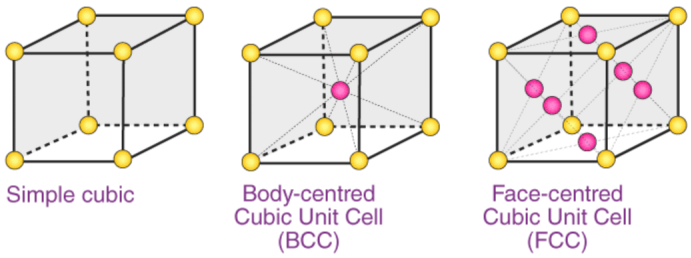

Figure 2: Various solid structures

7. (4 pts) **Osmotic Pressure** 0.020 M $C_6H_{12}O_6$(aq) solution (glucose) is separated from 0.050 M $CO(NH_2)_2$(aq) solution (urea) by a semipermeable membrane at 25°C. Report to 2 significant figures.

(a) Which solution has the higher osmotic pressure?

(b) Which solution becomes more dilute with the passage of water molecules through the membrane?

(c) To which solution should an external pressure be applied to maintain an equilibrium flow of water molcules across the membrane?

(d) What external pressure (in atm) should be applied in part (c)?

8. (4 pts) **Freezing Point Depression** *Extra Credit:* Colligative properties can be sources of insight not only for the properties of solutions, but also the properties of the solute. For example, acetic acid (CH_3COOH) behaves differently in two different solvents. Report to 3 significant figures.

(a) The freezing point of a 5.00% by mass aqueous acetic acid solution is -1.72°C. What is the molar mass of the solute? Explain any discrepancy between the experimental and the expected molar mass. Given water $k_f = 1.86\text{K}/m$.

(b) The freezing-point depression associated with a 5.00% by mass solution of acetic acid in benzene is 2.32°C. What is the experimental molar mass of the solute in benzene? What can you conclude about the nature of acetic acid in benzene? Given benzene $k_f = 5.12\text{K}/m$.

Optional Additional Problems: Ch. 12 - odd problems $25-47$, $79-85$; Ch. 13 - odd problems $25-35$, $47-55$, $65-93$