Practice#3 Additional Practice Problems for Colligative Properties

1)
Elemental analysis of an unknown pure substance indicated that the percent composition by mass is as follows.

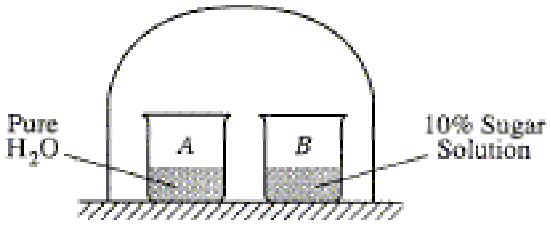
Element	Percent by Mass
Carbon	49.02%
Hydrogen	2.743%
Chlorine	48.23%

A solution that is prepared by dissolving 3.150 grams of the substance in 25.00 grams of benzene, C_6H_6, has a freezing point of 1.12°C. (The normal freezing point of benzene is 5.50°C and the molal freezing–point depression constant, K_f, for benzene is 5.12°C/molal.)

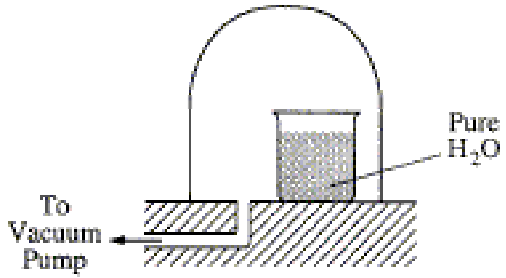
(a) Determine the empirical formula of the unknown substance.
(b) Using the data gathered from the freezing–point depression method, calculate the molar mass of the unknown substance.
(c) Calculate the mole fraction of benzene in the solution described above.
(d) The vapor pressure of pure benzene at 35°C is 150. millimeters of Hg. Calculate the vapor pressure of benzene over the solution described above at 35°C.

2)
Discuss the following phenomena in terms of the chemical and physical properties of the substances involved and general principles of chemical and physical change.

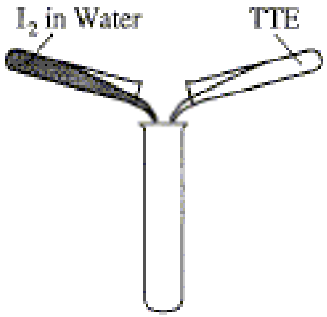
(a) As the system shown below approaches equilibrium, what change occurs to the volume of water in beaker A? What happens to the concentration of the sugar solution in beaker B? Explain why these changes occur.



(b) A bell jar connected to a vacuum pump is shown below. As the air pressure under the bell jar decreases, what behavior of water in the beaker will be observed? Explain why this occurs.



(c) A water solution of I_2 is shaken with an equal volume of a nonpolar solvent such as TTE (tri–chlorotrifluoroethane). Describe the appearance of this system after shaking. (A diagram may be helpful.) Account for this observation.



3)

An unknown compound contains only the three elements C, H, and O. A pure sample of the compound is analyzed and found to be 65.60 percent C and 9.44 percent H by mass.

(a) Determine the empirical formula of the compound.

(b) A solution of 1.570 grams of the compound in 16.08 grams of camphor is observed to freeze at a temperature 15.2 Celsius degrees below the normal freezing point of pure camphor. Determine the molar mass and apparent molecular formula of the compound. (The molal freezing-point depression constant, K_f, for camphor is 40.0 kg•K•mol^{-1}.)

(c) When 1.570 grams of the compound is vaporized at 300°C and 1.00 atmosphere, the gas occupies a volume of 577 milliliters. What is the molar mass of the compound based on this result?

(d) Briefly describe what occurs in solution that accounts for the difference between the results obtained in parts (b) and (c).

Answers to problems:

Question 1)

Answer:

(a)

moles / 100 g	C	H	Cl
	49.02/12.01	2.743/1.008	48.23/35.45
	= 4.081	= 2.722	= 1.360
mol ratio	3	2	1

empirical formula: C_3H_2Cl

(b) $\Delta T_f = (K_f)(m)$

$$4.38^{\circ} = \left(5.12^{\circ}/_{\text{molal}}\right) \times \frac{3.150^{\text{g}}/_{\text{molmass}}}{0.02500\text{kg}} = 147^{\text{g}}/_{\text{mol}}$$

c) mol fraction = mol benzene / total mol

$$= \frac{25.00/78.11}{\frac{3.150}{147} + \frac{25.00}{78.11}} = 0.938$$

(d) vapor pressure = mol fraction · P_o = (0.938)(150 mm) = 141 mm Hg

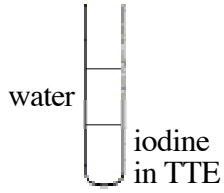
Question 2)

Answer:

(a) The volume of the water decreases while the concentration of sugar solution decreases.
Pure water has a higher vapor pressure than does the 10% sugar solution and when equilibrium is reached the water will evaporate and the solution will increase in volume.

(b) The water will boil when the pressure in the bell jar reaches the vapor pressure of the water. Boiling occurs when the vapor pressure of the liquid is in equilibrium with the pressure above the liquid.

(d) (i) Water and TTE will form separate layers because the polar water is not miscible with the non-polar TTE.



(ii) The TTE will be the bottom layer because its density is greater than the water.

(iii) The non-polar iodine will dissolve better in the non-polar TTE and form a pinkish-purple tint.

Question 3)

Answer

(a) C $\frac{65.60}{12.011} = 5.462$; H $\frac{9.44}{1.0079} = 9.37$; O $\frac{24.96}{16.00} = 1.56$

$\frac{5.462}{1.56} = 3.50$ $\frac{9.37}{1.56} = 6.00$ $\frac{1.56}{1.56} = 1.00$

$(C_{3.5}H_6O_1)_2 = C_7H_{12}O_2$

b) $\Delta T_{FP} = k_i m = k_i \frac{\text{mol solute}}{\text{kg solvent}} = k_i \frac{\frac{\text{g solvent}}{\text{molar mass}}}{\text{kg solvent}}$

$$\text{molar mass} = \frac{(\text{g solute})(k_\partial)}{(\text{kg solvent})(\Delta T_{FP})} = \frac{(1.570\ \text{g})(40.0\ \frac{\text{kg\_K}}{\text{mol}})}{(0.01608\ \text{kg})(15.2\_\text{C})} = 257\ \text{g/mol}$$

$C_7H_{12}O_2 = 128$ g/mol ; 257/128 = 2; 4, $(C_7H_{12}O_2)_2 = C_{14}H_{24}O_4$

(c) $PV = \frac{\text{grams}}{\text{molar mass}} RT$; molar mass = $\frac{\text{grams} \times R \times T}{P \times V}$

$$= \frac{(1.570\ \text{g}) \times (0.08205\ \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}) \times 573\text{K}}{1.00\ \text{atm} \times 0.577\ \text{L}} = 128\ \text{g/mol}$$

(d) since the apparent molar mass from freezing point change is twice that determined by the vapor, the mole-cules of the compound must associate in camphor to form dimers, **OR** the compound must dissociate in the gas phase.