Spring 2006 Laude CH302 Worksheet 3 covering Chapter 8 on Physical Equilibrium

1. Separate these compound into those that are polar (water soluble) and a non-polar(hydrophobic):
NaCl, NaCOOCH$_3$, cooking oil, HCl, CH$_4$, CH$_3$OH, CH$_3$CH$_2$OH, gasoline, N$_2$

Water soluble	Non-polar solvent soluble
NaCl, NaCOOCH$_3$, HCl, CH$_3$OH, CH$_3$CH$_2$OH	cooking oil, gasoline, CH$_4$

2. Rank the following substance in increasing order of vapor pressure:
NaCl, NH$_3$ solution, Vinegar (CH$_3$COOH), cooking oil, HCl, CH$_4$, He and H$_2$O.
NaCl, cooking oil, H$_2$O, Vinegar, HCl, NH$_3$ solution, CH$_4$, He

3. Rank the following solutes in terms of increasing solubility in the solvent:

Solvent	Solutes	Increasing solubility
Water	NaCl, H$_2$S, CH$_4$, NH$_3$	CH$_4$, H$_2$S, NH$_3$,NaCl
Hexane	NaCOOCH$_3$, cooking oil, CH$_3$OH, N$_2$	N$_2$, NaCOOCH$_3$, CH$_3$OH, cooking oil

4. A liquid is heated at atmospheric pressure. For each of the properties listed, predict whether they would increase or decrease in magnitude..
    (a) Viscosity
        Decrease
    (b) Density
        Decrease
    (c) Surface Tension
        Decrease
    (d) Vapor Pressure
        Increase
    (e) Tendency to Evaporate
        Increase

5. Calculate the amount of heat (J) required converting 180 g of water at 10.0°C to steam at 105.0°C. Use constants found in the lecture notes for this calculation.

180 g H2O x (2.26 x 10^3 J/g) = 4.07 x 10^5 J
180 g H2O x (2.03 J/g. °C) x (105.0°C – 100.0°C) 1.8 x 10^3J = 0.018 x 10^5 J
Total heat = 6.77 x 10^4 J + 4.07 x 10^5 J + 0.018 x 10^5 J = 4.76 x 10^5 J

6. The molar heat of fusion, ΔH_{fus}, of Na is 2.6 kJ/mol at its melting point, 97.5°C. How much heat must be absorbed by 5.0g of solid Na at 97.5°C to melt it?

5.0 g Na x (1 mol Na/23 g Na) x (2.6 kJ/1 mol Na) = 0.57 kJ

7. How much heat would be required to convert 234.3 g of solid benzene, C$_6$H$_{6(s)}$, at 5.5 °C into benzene vapor, C$_6$H$_{6(g)}$, at 100.0 °C? Benzene has the following molar heat capacities: C$_6$H$_6$(l) = 136 J/mol °C, and C$_6$H$_6$(g) = 81.6 J/mol °C. The molar heat of fusion for benzene is 9.92 kJ/mol and the molar heat of vaporization for benzene is 30.8 kJ/mol. The melting point of benzene is 5.5 °C; and the boiling point of benzene is 80.1 °C. Benzene's molecular weight is 78.0 g/mol.

$$234.5\,\text{g} \times \frac{\text{mol}}{78.0\,\text{g}} = 3\,\text{mol}$$

$C_6H_{6(s)}$, 5.5 °C→$C_6H_{6(l)}$, 5.5 °C→$C_6H_{6(l)}$, 80.1 °C→$C_6H_{6(g)}$, 80.1 °C→$C_6H_{6(g)}$, 100.0 °C
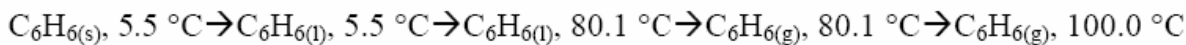
Step 1: $\dfrac{9.92\,\text{kJ}}{\text{mol}} \times (3\,\text{mol}) = 29.8\,\text{kJ}$

Step 2: $\dfrac{136\,\text{J}}{\text{mol}\cdot°\text{C}} \times (3\,\text{mol}) \times (80.1-5.5)°\text{C} = 30{,}437\,\text{J} = 30.4\,\text{kJ}$

8. Choose the ion in each pair that would be more strongly hydrated in aqueous solution and justify your answer:
(a) Na^+ or Rb^+ **(b)** Cl^- or Br^- **(c)** Fe^{3+} or Fe^{2+} **(d)** Na^+ or Mg^{2+}
Charge density arguments explain the answers. The bigger the charge density, the more hydrated.

9. In Denver, the partial pressure of oxygen is 0.17 atm. What is the molar solubility of oxygen there at 20°C? Henry Law constant for oxygen at 20°C is 0.0013 mol/L atm.
$S = k_H P = (.0013\ \text{mol}/\text{L atm} * .17\ \text{atm}) = 2.21\text{e-}4\ \text{mol/L}$

10. What is the molality of a solution that contains 128 g of CH_3OH in 108g of water?
128 g CH_3OH x 1 mol CH_3OH = 37.0 mol = 37.0 m
0.108 kg H_2O 32.0g CH_3OH kg H_2O

11. (a) How many grams of H_2O must be used to dissolve 50.0 g of sucrose, $C_{12}H_{22}O_{11}$, to prepare a 1.25 m solution of sucrose?
50.0g $C_{12}H_{22}O_{11}$ x 1 mol $C_{12}H_{22}O_{11}$ = 0.146 mol $C_{12}H_{22}O_{11}$
342 g $C_{12}H_{22}O_{11}$
0.146 mol $C_{12}H_{22}O_{11}$ = 0.117 kg H_2O = 117 g H_2O
1.25 mol $C_{12}H_{22}O_{11}$/ kg H_2O
(b) Predict the boiling point of this solution; K_b for H_2O is 0.512°C/m.
$\Delta T_b = (0.512°\text{C}/m)(1.25m) = 0.640°\text{C}$; BP= 100°C + 0.64°C = 100.64°C
(c) Calculate the freezing point of this solution; K_f for H_2O is 1.86°C/m.
$\Delta T_f = (1.86°\text{C}/m)(1.25m) = 2.32°\text{C}$
$T_{f(solution)} = 0.00°\text{C} - 2.32°\text{C} = -2.32°\text{C}$
(d) What osmotic pressure would this solution exhibit at 25°C? Its density is 1.34g/mL.
167 g x 1mL = 125mL = .125L
1.34g
$M_{sucrose} = 0.146$ mol = 1.17 mol/L
0.125 L
$\pi = MRT = (1.17\text{mol/L})(0.0821\ \text{L.atm/mol.K})(298\text{K}) = 28.6$ atm

12. What are the mole fractions of CH_3OH and H_2O in the solution described in #1? It contains 128 g of CH_3OH and 108 g of H_2O.
128g CH_3OH x 1 mol CH_3OH = 4.00 mol CH_3OH
32.0 g CH_3OH
108 g H_2O x 1 mol H_2O = 6.00 mol H_2O
18.0 g H_2O
$X_{CH3OH} = 4$ mol = 0.400; $X_{H2O} = 6$ mol = 0.600
(4+6) mol   (4+6) mol

13. (a) At 40°C, the vapor pressure of pure heptane is 92.0 torr and the vapor pressure of pure octane is 31.0 torr. Consider a solution that contains 1.00 mole of heptane and 4.00 moles of octane. Calculate the vapor pressure of each component and the total vapor pressure above the solution.

$X_{heptane}$ = 1 mol heptane = 0.200; X_{octane}= 1 - $X_{heptane}$ = 0.800
(1 mol heptane + 4 mol octane)
$P_{heptane}$ = $X_{heptane}P_0$
heptane = (0.2)(92.0 torr) = 18.4 torr
P_{octane} = $X_{octane}P_0$
octane = (0.8)(31.0 torr) = 24.8 torr
P_{total} = $P_{heptane}$ + P_{octane} = 18.4 torr + 24.8 torr = 43.2 torr

(b) Calculate the mole fractions of heptane and octane in the vapor that is in equilibrium with this solution.

$X_{heptane}$ = $P_{heptane}$ = 18.4 torr = 0.426; X_{octane}= P_{octane} = 24.8 torr = 0.574
P_{total} 43.2 torr P_{total} 43.2 torr

14. When 15.0g of ethyl alcohol, C_2H_5OH, is dissolved in 750 grams of formic acid, the freezing point of the solution is 7.20°C. The freezing point of pure formic acid is 8.40°C. Solve for K_f for formic acid.

15.0g C_2H_5OH x 1 mol C_2H_5OH = 0.435 m
0.750 kg formic acid 46.0 g C_2H_5OH
ΔT_f = ($T_{f(formic\ acid)}$) − ($T_{f(solution)}$) = 8.40°C − 7.20°C = 1.20°C
K_f = ΔT_f = 1.20°C = 2.76°C/m
m 0.435m

15. A 1.20 gram sample of an unknown covalent compound is dissolved in 50.0 g of benzene. The solution freezes at 4.92°C. Calculate the molecular weight of the compound. The freezing point of pure benzene is 5.48°C and K_f is 5.12°C/m.

ΔT_f = 5.48°C − 4.92°C = 0.56°C; m = ΔT_f = 0.56°C = 0.11m
K_f 5.12°C/m
(0.11m)(0.0500kg) = 0.0055 mol solute
1.20 g solute = 0.022 g/mol
0.0055 mol solute

16. 0.500 grams of a sample is dissolved in 30mL of aqueous solution. If this solution has an osmotic pressure of 8.92 torr at 27.0°C, estimate its molecular weight.

π = MRT = (n/V)RT; n = πV = (8.92 torr x 1 atm/760 torr)(0.0300L) =0.0000143 mol
RT (0.0821 L.atm/mol.K)(300K)
0.500 g/0.0000143 mol = 3.50 x 10$_4$ g/mol

17. Rank the following in terms of increasing boiling point elevation when 0.1 moles of each is placed in 1 liter of water.

NaCl $BaSO_4$ $CaCl_2$ Urea (a nonionizable, water soluble organic molecule)

$BaSO_4$ < urea < NaCl< $CaCl_2$ (remember that BaSO4 is insoluble)

18. Predict the temperature at which water boils if it has a vapor pressure of 355 torr at 80°C. The ΔH^o_{vap} of water is 40.7 kJ/mol.

Use the Clausius Clapeyron equation and follow my approach in the notes. Make sure you change torr to Pa and you should get a value a little over 373 K depending on how many sig figs you use in your constants.