HW 7

Chem 3321 homework #7 out of 70 marks – due April 10, 2023

Problem 1, 10 marks

By measuring the equilibrium between the liquid and vapor phases of an acetone (A) - ethanol (E) solution at 57.2 °C and 1.00 atm it was found that $x_A = 0.400$ and $y_A = 0.516$. Calculate the activities and activity coefficients for both components in this solution using the Raoult's law basis. The vapor pressure of the pure components at this temperature are: $P_A^* = 786$ torr and $P_E^* = 551$ torr. (x_A is the mole fraction in the liquid and y_A the mole fraction in the vapor.)

(γ) Activity Coefficient - measure of how much a solution differs from an ideal solution

(a) Activity - measure of "effective concentration" of a species in mixture

$\gamma_a = a_A / X_A$ $a_A = P_A / P_A^*$ $P_a = y_a P_{TOT}$

$P_{TOT} = 1$ atm

convert since everything is in Torr so,

$P_{TOT} = 760$ Torr

$P_a = (0.516)(760) =$ answer

then plug answer into:

$a_A = P_A / P_A^* =$ answer

$a_E = P_E / P_E^* =$ answer (where $P_E = 1 - P_A$)

then,

$\gamma_A = a_A / X_A =$ answer

and

$\gamma_E = a_E / X_E =$ answer (where $X_E = 1 - X_A$)

You should have 4 answers, the activity and activity coefficient for both Ethanol and acetone

Problem 2, 10 marks

The total vapor pressure of a 4 mol % solution of NH_3 in water is 50.00 mm Hg at 20 °C; the vapor pressure of pure water is 17.00 mm Hg at this temperature. Apply Henry's and Raoult's laws to calculate the two partial pressures and the total vapor pressure of a 5 mol % solution.

P_{tot} (above 50.00 mm Hg); $P^*_{H_2O}$ (above 17.00 mm Hg)

Raoult's Law: $P_A = X_A P^*_A$

Henry's Law: $P_A = K_H X_A$

Dalton's Law: $P_{total} = P_A + P_B$

$X_{NH_3} = \frac{4}{100} = 0.04$

$X_{H_2O} = 100 - 0.04 = 0.96$

Dalton's

$$P_{total} = \underbrace{K_H X_{NH_3}}_{\text{Henry's}} + \underbrace{X_{H_2O} P^*_{H_2O}}_{\text{Raoult's}}$$

solve for K_H

then, at 5%,

$X_{NH_3} = \frac{5}{100} = 0.05$

$X_{H_2O} = 100 - 0.05 = 0.95$

so, $P_{NH_3} = K_H X_{NH_3}$ (Henry's)

and, $P_{H_2O} = X_{H_2O} P^*_{H_2O}$ (Raoult's)

then, $P_{tot} = P_{NH_3} + P_{H_2O}$ (Dalton's)

You should have 3 answers at the end.

Problem 3, 10 marks

K_H

The average human with a body weight of 70. kg has a blood volume of 5.00 L. The Henry's law constant for the solubility of N_2 in H_2O is 9.04×10^4 bar at 298 K. Assume that this is also the value of the Henry's law constant for blood and that the density of blood is 1.00 kg L^{-1}.

(a) Calculate the number of moles of nitrogen absorbed in this amount of blood in air of composition 80.% N_2 at sea level, where the pressure is 1 bar, and at a pressure of 50. bar.

$X_{N_2} = \frac{n_{N_2}}{n_{N_2} + n_{H_2O}}$ and $P_{N_2} = X_{N_2} K_H$

so,

$P_{N_2} = \frac{n_{N_2}}{n_{N_2} + n_{H_2O}} K_H$

then ↓

$n_{N_2} = \frac{P_{N_2} n_{H_2O}}{K_H - P_{N_2}}$ (at 1 bar)

$1 L = 1 \times 10^3 g$

$n_{H_2O} = \frac{(5 \times 10^3 g)}{(18.02 g/mol)}$

$n_{H_2O} = 277 mol$

and $K_H = 9.04 \times 10^4$ bar

$X_{N_2} = \frac{80}{100} = 0.80$

$P_{N_2} = X_{N_2} P^*_{N_2}$

$P_{N_2} = (0.80)(1 bar)$

$P_{N_2} = 0.80$ bar

plug in & solve. what about at 50bar? multiply by 50

(b) Assume that a diver accustomed to breathing compressed air at a pressure of 50. bar is suddenly brought to sea level. What volume of N_2 gas is released as bubbles in the diver's bloodstream? (The volume of N_2 you calculate is far more that is needed to cause the formation of arterial blocks due to gas-bubble embolisms.)

$\Delta n = n_{N_2}^{50bar} - n_{N_2}^{1bar}$ = answer

$PV = nRT$

$V = \frac{nRT}{P}$ and solve.

Problem 4, 10 marks

The partial molar volumes of water and ethanol in a solution with $x_{H_2O} = 0.45$ at 25°C are 17.0 and 57.5 $cm^3 mol^{-1}$ respectively. Calculate the volume change upon mixed sufficient ethanol with 3.75 mol of water to give this concentration. The densities of water and ethanol are 0.997 and 0.7893 g cm^{-3} respectively at this temperature.

$X_{H_2O} = 0.45$ $\bar{V}_{H_2O} = 17\ cm^3/mol$ $\bar{V}_E = 57.5\ cm^3/mol$ $T = 298$

$V = \frac{m}{D}$

$\bar{V}^*_{H_2O} = \frac{18.02g/mol}{0.997g/cm^3} =$ answer

$X_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + n_E}$

$0.45 = \frac{3.75\ mol}{3.75\ mol + n_E}$ solve for n_E

$\bar{V}^*_E = \frac{46.07g/mol}{0.7893g/cm^3} =$ answer

then, $\Delta V = V_2 - V_1$ and $V = \bar{V}n$

$$\Delta V = (n_{H_2O})(\bar{V}_{H_2O} - \bar{V}^*_{H_2O}) + (n_E)(\bar{V}_E - \bar{V}^*_E)$$

Problem 5, 10 marks

A solution of sucrose in water freezes at -0.200 °C. Calculate the vapor pressure of this solution at 25 °C (accurate to 0.001 mm Hg). The vapor pressure of pure water at 25 °C is 23.506 mm Hg and the molal freezing-point constant for water is 1.86 °C/m. → K_f

mol/kg

$P_{H_2O} = X_{H_2O} P^*_{H_2O}$

answer

$X_{suc} = \frac{n_{suc}}{n_{suc} + n_{H_2O}}$

$\Delta T_{fus} = K_f \cdot M$

*can keep in °C since they cancel out

molality

$X_{suc} = \frac{m}{\left(\frac{1000 g/kg}{M_j}\right) \cdot m}$

molality

molar mass of solvent

18 g/mol for H_2O

$0°C - (-0.2°C) = 1.86 °C/m \cdot M$

solve for M (in mol/kg)

$X_{H_2O} = 1 - X_{suc}$

$X_{suc} = \frac{M \cdot \text{molar mass of } H_2O}{1000 \text{ g} \cdot \text{kg}}$

Plug in & solve

Problem 6, 10 marks

Calculate the osmotic pressure of a 2 molal aqueous solution of sucrose at room temperature assuming ideal (Raoult's Law) behavior. Compare to the value of $\pi = 58.0$ atm which accounts for non-ideal behavior.

$\pi = CRT$ where $C = M \cdot \rho_{H_2O}$ * assume density of dilute solution is the density of pure water. (0.997 g/mL at 298 K)

$C = M \cdot \rho_{H_2O}$ (M → molality)

$C = 2\,mol/kg \cdot \rho_{H_2O}$

↓

$C = \frac{2\,mol}{1000\,g\,H_2O} \cdot \frac{0.997\,g}{1\,mL} \cdot \frac{1000\,mL}{1\,L}$ = answer in $\frac{mol}{L}$

then plug into $\pi = CRT$ → (KELVIN) to get π_{ideal}

comparison: $\% = \frac{\pi_{non\text{-}ideal} - \pi_{ideal}}{\pi_{non\text{-}ideal}} \times 100$

2 answers expected!

Problem 7, 10 marks

2.20 g of a polymer is dissolved in enough water to make 300 mL of solution. The osmotic pressure is found to be 7.45 torr at 20 °C. Determine the molar mass of the polymer.

m (2.20 g); 0.3 L (300 mL); π (7.45 torr); 293K (20 °C); M (molar mass)

$\pi = CRT$

$C = \frac{\pi}{RT}$ = answer (plug in)

* $R = 62.36 \frac{L \cdot Torr}{K \cdot mol}$

If you don't use this I will come out wrong.
* unless you convert

$C = \frac{m}{M \cdot V}$

Then,

M (molar mass) $= \frac{m \text{ (mass)}}{C \cdot V}$ = answer in g/mol