Chem 3321, some practice questions for test #2

I want complete, detailed answers to the questions. Show all your work to get full credit.

DATA:

R = 0.082 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1}

1 atm = 1.01×10^5 Pa = 1.01 bar = 760 torr

1 mL = 1 cm^3

1 Pa = 1 N m^{-2}

0 °C = 273 K

Avogadro's constant = N$_A$ = 6.022×10^{23} mol^{-1}

π = 3.14159

1 eV = 1.6022×10^{-19} J (electron volt to joule conversion)

mass conversion from amu to kg: 1.66×10^{-27} kg/amu

$C_P - C_V = nR$ for any ideal gas

I'm including the names in case he asks concept questions and the names help.

★ remember when to use, with gas

$$\ln\left[\frac{P_2}{P_1}\right] = -\frac{\Delta H}{R} \cdot \left(\frac{1}{T_2} - \frac{1}{T_2}\right)$$ *Clausius - Clapeyrion Eq.*

$$\Delta V = (n_1 \bar{V}_1 + n_2 \bar{V}_2) - (n_1 V_1^* - n_2 V_2^*)$$

Raoult's Law

$$P_A = X_A P_A^*$$

$$P_B = X_B P_B^*$$

Dalton's Law

$$P_{tot} = P_A + P_B$$

Dissociating

$$PL \rightleftharpoons P + L$$

$$K_D = \frac{[P][L]}{[PL]}$$

$$\Delta G° = -RT \ln K$$

Problem 1

From the following data, determine the total volume change for dissolving glycine in 1 kg water to 1 molal concentration. Note: 1 kg H_2O = 55.51 mol. Note: 1 molal concentration means that 1 mol of glycine is dissolved in 1 kg of water.

glycine concentration	glycine	water
molality	$\bar{V}$, cm³mol⁻¹	$\bar{V}$, cm³mol⁻¹
before 0	–	18.07
after 1	44.88	18.05
before pure glycine	46.71	–

write on notecard

$$\Delta V = (n_1 \bar{V}_1 + n_2 \bar{V}_2) - (n_1 V_1^* + n_2 V_2^*)$$

$$\left[\overset{n_1}{55.51\,mol} \overset{\bar{V}_1}{(18.05)} + \overset{n_2 \ \bar{V}_2}{1(44.88)} \right] - \left[\overset{n_1}{55.51} \overset{V_1^*}{(18.07)} + \overset{n_2 \ V_2^*}{1(46.71)} \right]$$

answer: $-2.94\ cm^3$

Problem 2 *Like the HW* ΔH ↑

The molar enthalpy of vaporization of water is 40.65 kJ mol^{-1} at its normal boiling point
of 100 °C. Determine the vapor pressure of water at 110 °C. $\searrow$ 383.15K = T_2

T_1
373.15K $\smile$

$$\ln\left[\frac{P_2}{P_1}\right] = -\frac{\Delta H}{R} \cdot \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$ Clausius - Clapeyron Eq.

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convert from KJ to J to make
life easier ↓

$$\ln\left[\frac{P_2}{1\,atm}\right] = \frac{-40650\,J/mol}{8.3145}\left(\frac{1}{383.15} - \frac{1}{373.15K}\right)$$

$$\ln\left[\frac{P_2}{1\,atm}\right] = .3419$$

$$\frac{P_2}{1\,atm} = e^{.3419}$$

answer

$$P_2 = 1.408\,atm$$

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Problem 3

so, mole fraction of methanol = 0.6

A solution of acetone (A) and methanol (M) are in equilibrium at 57.2 °C and 1.0 atm. The mole fraction of acetone in the liquid phase is 0.400. Determine mole fraction of acetone in the vapor phase. For these two components, $P_A^* = 105$ kPa and $P_M^* = 73.5$ kPa.

Raoult's Law

$$P_A = X_A P_A^* = 0.4 \times 105 \, kPa = 42 \, kPa$$

$$P_B = X_B P_B^* = 0.6 \times 73.5 \, kPa = 44.1 \, kPa$$

Dalton's Law

$$P_{tot} = P_A + P_B = 42 \, kPa + 44.1 \, kPa = 86.1 \, kPa$$

so, mole fraction is

$$y_A = \frac{P_A}{P_{total}} = \frac{42 \, kPa}{86.1 \, kPa} =$$

answer

$$y_a = 0.4878$$

* unitless

Problem 4

N_2O_3 dissociates according to the equilibrium

$$N_2O_3\,(g) \rightleftharpoons NO_2\,(g) + NO\,(g) \tag{1}$$

At 298 K and 1 bar pressure, the degree of dissociation is 3.5×10^{-3}, where the degree of dissociation is defined as the ratio

$$\frac{\text{moles of NO}_2 \text{ or NO}}{\text{moles of the reactant before any dissociation occurs}} \tag{2}$$

Calculate ΔG° for this reaction.

First, create I.C.E table:

$$N_2O_3\,(g) \rightleftharpoons NO_2\,(g) + NO\,(g)$$

	$N_2O_3\,(g)$	$NO_2\,(g)$	$NO\,(g)$
I	n_0	0	0
C	$-x$	$+\ x$	x
E	$n_0 - x$	$+\ x$	x

$(n_0 - x) + x + x$

$n_0 + x$

$$\frac{P_{NO}}{P_{total}} = \frac{x}{n_0 + x} \qquad \frac{P_{NO_2}}{P_{total}} = \frac{x}{n_0 + x} \qquad \frac{P_{N_2O_3}}{P_{total}} = \frac{n_0 - x}{n_0 + x}$$

Dissociating

$$PL \rightleftharpoons P + L$$

$$K_p = \frac{[P][L]}{[PL]} = \frac{\left(\frac{x}{n_0 + x}\right) \cdot \left(\frac{x}{n_0 + x}\right)}{\left(\frac{n_0 - x}{n_0 + x}\right)} = \left(\frac{x^2}{(n_0 - x)(n_0 + x)}\right)\left(\frac{1}{n_0}\right)^2$$

$$= \frac{(x^2)\left(\frac{1}{n_0}\right)^2}{(n_0 - x)(n_0 + x)\left(\frac{1}{n_0}\right)^2} = \frac{(x/n_0)^2}{(1 - x/n_0)(1 + x/n_0)} = \frac{y^2}{(1 - y)(1 + y)}$$

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Then, plug 3.5×10^{-3} for y

$$\frac{(3.5 \times 10^{-3})^2}{(1 - 3.5 \times 10^{-3})(1 + 3.5 \times 10^{-3})} = 1.225 \times 10^{-5}$$

then, plug into:

$$\Delta G^\circ = -RT \ln K$$

$$\boxed{\left(\frac{1}{d_0}\right)^2} \quad K_d = \frac{mol \cdot mol}{liz^l} \left(\frac{mol(\frac{\pi}{2})}{mol}\right) \quad 0 \qquad \frac{0}{0}$$

$$K_d = \frac{}{} \quad \left(mole/mol\right)$$

$$K_d$$

$$y$$

answer:

$\Delta G^\circ = 28.02 \, kJ/mol$

$$\Delta G = \underline{\Delta H_m} \left(1 - \frac{T}{T_m}\right) + \underline{\Delta C_p} \left\{ \left(T - T_m\right) - T_m \left(\frac{T}{T_m}\right) \right\}$$

✻ expected to derive this formula. Expect on test

Problem 5

a) Prove that (where K is the equilibrium constant)

$$\ln K = -\frac{\Delta H°}{RT} + \frac{\Delta S°}{R} \tag{3}$$

b) Compute $\Delta H°$ and $\Delta S°$ for the reaction $2NO_2(g) \rightleftharpoons N_2O_4(g)$

given the following data: K at T = 273 K is 72.9 and K at T = 325 K is 1.30.

a) This is the van't Hoff eq: $\underline{\Delta G = -RT \ln K}$
$\overline{-RT} \quad -RT$

use: $\boxed{\Delta G = \Delta H - T\Delta S}$

$\ln K = \frac{\Delta G}{-RT} \quad = \quad \ln K = \frac{\Delta H - T\Delta S}{-RT}$

and $\boxed{\Delta G° = -RT \ln K}$

$= \ln K = \frac{\Delta H}{RT} - \frac{T\Delta S}{RT} \quad \boxed{\ln K = \frac{\Delta H}{RT} - \frac{\Delta S}{R}}$

b) Look at Problem 3 in HW 6. Hoff eq. is identical to

$K_1 = 72.9 \qquad K_2 = 1.30$

$T_1 = 273 \qquad T_2 = 325$

Clausius - Clapeyron

$(K p(T) = P(T))$

$\ln\left(\frac{1.30}{72.9}\right) = \frac{-\Delta H}{8.314}\left(\frac{1}{325} - \frac{1}{273}\right)$ $\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$-4.0267 = \frac{-\Delta H}{8.314}\left(-0.000586\right)$ $\Delta H = -57.1 \, kJ/mol$

Then,

$\ln K = \frac{\Delta H}{RT} - \frac{\Delta S}{R}$

$\Delta S = \left(\frac{\Delta H}{RT} - \ln K\right) \cdot R$ $\Delta S = -174 \, J/mol$

$\Delta S = \left(\frac{-57.1 kJ/mol}{R \cdot 273} - \ln 72.9\right) \cdot R$