

Quiz 3  
CH 353 Sumer 2009

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Name: \_\_\_\_\_

KEY

Carefully read all the problems. The exam should have 4 questions on 6 pages. The first page has potentially useful information. The last page is for extra writing space.

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \quad R = 8.314 \times 10^{-2} \text{ L bar K}^{-1} \text{ mol}^{-1} \quad R = 8.206 \times 10^{-2} \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$1 \text{ atm} = 1.01325 \text{ bar} \quad T/\text{K} = T/^{\circ}\text{C} + 273.15 \quad 1 \text{ atm-L} = 101.325 \text{ J} \quad 1 \text{ bar-L} = 100 \text{ J}$$

$$g = 9.8 \text{ m s}^{-2} \quad \Pi = \rho gh$$

$$\frac{dP}{dT} = \frac{\Delta S}{\Delta V} = \frac{\Delta H}{T\Delta V} \quad \ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H}{R} \left[ \frac{1}{T_2} - \frac{1}{T_1} \right] \quad P_i = \chi_i P_i^*$$

$$\Delta T = KX_B \quad K \equiv \frac{RT_b^{*2}}{\Delta_{\text{VAP}}H} \quad \Delta T = K_b m \quad \Delta T = K'X_B \quad K' \equiv \frac{RT_m^{*2}}{\Delta_{\text{FUS}}H} \quad \Delta T = K_f m$$

$$\Pi = \frac{n_B}{V} RT = [B]RT$$

$$\left(\frac{\partial \mu}{\partial P}\right)_T = V_M \quad \left(\frac{\partial \mu}{\partial T}\right)_P = -S_M$$

**Please sign at the bottom to certify that you have worked on your own.**

I certify that I have worked the following exam without the help of others, and that the work I am turning in is my own.

Signed: \_\_\_\_\_

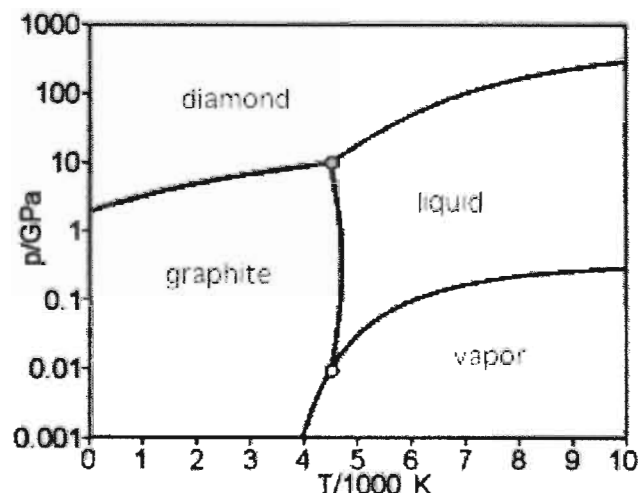
Signature

Date

1. True/False Circle either T or F for each statement (10 points each)

- T  F In osmosis the membrane can pass the solute, but blocks the solvent.
- T  F A 1 M solution of NaCl in water will freeze at the same temperature as a 1 M solution of sugar in water.
- T  F The temperature the triple point changes dramatically with changes in the pressure since the properties of gases are strongly dependent on pressure.
- T F The chemical potential of every substance decreases with increasing temperature at constant pressure.
- T F The chemical potential of toluene in a 1M solution of naphthalene (solute) in toluene (solvent) is lower than the chemical potential of pure toluene.

2A. (25 points) Given the following phase diagram of carbon answer the following and provide an explanation



1. Is density of liquid carbon every higher than the density of graphite?

8 Yes  $P > 1 \text{ GPa}$

2. Given that diamond has a higher density than graphite, which has a higher entropy?

8 slope  $\frac{\Delta S}{\Delta V} > 0$ ,  $\Delta V < 0$ ,  $S < 0$   $S_{\text{graphite}} > S_{\text{diamond}}$

3. What is the vapor pressure of liquid carbon at 5000 K. (note the pressure is in Gigapascal or  $10^9 \text{ Pa}$  and is shown on a log scale)

9  $\sim 2 \times 10^7 \text{ Pa}$  (0.02 GPa)

2B. (25 points)

What is the freezing point of a solution made of 100 mL of water and 5 g of NaCl

Water

Density =  $1.0 \text{ g cm}^{-3}$

$K_b = 1.86 \text{ }^\circ\text{C m}^{-1}$

$K_f = 0.5 \text{ }^\circ\text{C m}^{-1}$

$T_m = 0.0 \text{ }^\circ\text{C}$

$$m = \frac{5 \text{ g/mol}}{58.45 \text{ g/mol} / 0.1 \text{ kg}} = 0.855 \text{ mol kg}^{-1}$$

$$\Delta T = -(2)(0.5 \text{ }^\circ\text{C m}^{-1})(0.855 \text{ m}) = -0.855 \text{ }^\circ\text{C}$$

$$(\text{solution}) T_m = 0 - 0.855 = -0.855 \text{ }^\circ\text{C}$$

$$\begin{aligned} & \text{(WRONG!)} \\ & 272.3 \text{ K} \end{aligned}$$

$i \neq 2$  (-7)

wrong sign (-7)

3. (50 points)

You have a closed container into which you place two beakers. The first beaker (#1) contains 10 grams of sucrose ( $MW = 342 \text{ g mol}^{-1}$ ) and 100 mL of water, the second beaker (#2) contains 30 grams of sucrose and 100 mL of water. The entire container is sealed and held a constant temperature of  $25^\circ\text{C}$ . The vapor pressure of pure water at  $25^\circ\text{C}$  is 0.0317 bar and sucrose is non-volatile

Initially which beaker has the higher vapor pressure or are they the same?

10 Beaker 1 (10g sucrose)

You then leave the two solutions in the container for a very long time and let them come to equilibrium. After they have reached equilibrium what are:

At equilibrium,  $\chi_{\text{H}_2\text{O}}$  (Beaker 1) =  $\chi_{\text{H}_2\text{O}}$  (Beaker 2)

The mole fraction of water of the solution in beaker #1

10 
$$\chi_{\text{H}_2\text{O}} = \left( \frac{200 \text{ g H}_2\text{O} \left| \frac{1 \text{ mol}}{18 \text{ g}} \right.}{\frac{200 \text{ g}}{18 \text{ g mol}^{-1}} + \frac{40 \text{ g}}{342 \text{ g mol}^{-1}}} \right) = 0.9896$$

The mole fraction of water of the solution in beaker #2

10 
$$\chi_{\text{H}_2\text{O}} = 0.9896$$

The partial pressure of water in the container

10 
$$P_{\text{H}_2\text{O}} = \chi_{\text{H}_2\text{O}} P_{\text{H}_2\text{O}}^* = (0.9896)(0.0317 \text{ bar}) = 0.0314 \text{ bar}$$

What is the change in chemical potential between the initial and final states of the system (everything in the container)?

10 Everyone received credit for this question.

Note: you can assume the total amount of vapor is very small and doesn't significantly change the total volume of liquid. You can assume these are ideal solutions

4. (50 points)

Substance X has a triple point at 25°C with a vapor pressure of 250 Torr. The vapor pressure of the liquid is 500 Torr at 40°C. What is  $\Delta_{\text{VAP}}H^\circ$ ? What is  $\Delta_{\text{FUS}}H^\circ$ ? What is the melting temperature of X at 500 bar?

$$\Delta_{\text{SUB}}H^\circ = 48 \text{ kJ mol}^{-1}$$
$$\text{density (s)} = 3.2 \text{ g cm}^{-3}$$
$$\text{density (l)} = 3 \text{ g cm}^{-3}$$
$$\text{MW} = 40 \text{ g mol}^{-1}$$
$$\ln\left(\frac{500}{250}\right) = -\frac{\Delta_{\text{VAP}}H}{R} \left[ \frac{1}{313.15} - \frac{1}{298.15} \right]$$

$$\textcircled{+15} \quad \Delta_{\text{VAP}}H = 35.87 \text{ kJ mol}^{-1}$$

$$\textcircled{+5} \quad \Delta_{\text{FUS}}H = \Delta_{\text{SUB}}H - \Delta_{\text{VAP}}H = (48 - 35.87) = 12.1 \text{ kJ mol}^{-1}$$

$$\frac{\Delta P}{\Delta T} \approx \text{slope} \approx \frac{\Delta H}{T \Delta V}$$

$$\Delta V = \frac{1}{3} - \frac{1}{3.2} = 0.0208 \text{ cm}^3 \text{ g}^{-1}$$

$$\textcircled{+10} \quad \Delta V = \frac{0.0208 \text{ g}^{-1} \text{ cm}^3 \mid 40 \text{ g} \mid 10^{-3} \text{ L}}{\text{mol} \mid 1 \text{ cm}^3} = 8.32 \times 10^{-4} \text{ L mol}^{-1}$$

$$\textcircled{+10} \quad \frac{\Delta P}{\Delta T} = \frac{12.1 \text{ kJ mol}^{-1} (10^3) \left( \frac{1 \text{ L bar}}{100 \text{ J}} \right)}{(298 \text{ K}) (8.32 \times 10^{-4} \text{ L mol}^{-1})} = 488 \text{ bar K}^{-1}$$

$$\Delta T = \frac{\Delta P}{488 \text{ bar K}^{-1}} \quad \Delta P = 500 \text{ bar} - \frac{250 \text{ Torr}}{760 \text{ Torr}} \left( \frac{1.013 \text{ bar}}{\text{atm}} \right)$$

$$\Delta P = 499.6 \text{ bar}$$

$$\Delta T = \frac{499.6 \text{ bar}}{488 \text{ bar K}^{-1}} = 1.0 \text{ K}$$

$\textcircled{+10}$

$$T_m(500 \text{ bar}) = 25^\circ\text{C} + 1.0^\circ\text{C} = 26^\circ\text{C}$$

Another way to calculate equilibrium mol fractions of  $H_2O$  in problem 3:

At equilibrium, you ~~know~~ know that the mol fraction of  $H_2O$  must be equal in both beakers. Since the solute (sugar) cannot "move", the water must evaporate and recondense into the beaker with more sugar (Beaker 2). In the end (at equilibrium), 50 mL of  $H_2O$  from Beaker 1 will travel to Beaker 2, leaving a ratio of 10g sugar : 50 mL  $H_2O$  in both Beakers. Thus,

$$x_{\text{final}}(\text{Beaker 1}) = \frac{50 \text{g } H_2O / 18 \text{g mol}^{-1}}{50 \text{g} / 18 \text{g mol}^{-1} + 10 \text{g} / 340 \text{g mol}^{-1}} = 0.9896$$

$$x_{\text{final}}(\text{Beaker 2}) = \frac{150 \text{g } H_2O / 18 \text{g mol}^{-1}}{150 \text{g } H_2O / 18 \text{g mol}^{-1} + 30 \text{g sugar} / 340 \text{g mol}^{-1}} = 0.9896$$