Quiz III

CH 353 Sumer 2008

Vanden Bout

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 J K^{-1} mol^{-1} R = 8.314x10^{-2} L bar K^{-1} mol^{-1} R = 8.206x10^{-2} L atm mol^{-1} K^{-1}

1 atm = 1.01325 bar T/K = T/°C + 273.15 1 atm-L = 101.325 J 1 bar-L = 100 J

g = 9.8 m s^{-2} $\Pi = \rho g h$

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

$$\Delta T = K X_B \quad K \equiv \frac{R T_b^{*2}}{\Delta_{VAP} H} \quad \Delta T = K_b m \qquad \Delta T = K' X_B \quad K' \equiv \frac{R T_m^{*2}}{\Delta_{FUS} H} \quad \Delta T = K_f m$$

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

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

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 The liquid phase is never stable at temperatures lower than the temperature at the triple point

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 vapor pressure of solid CO_2 is higher than that of liquid CO_2 at some temperatures.

(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 in toluene is lower than the chemical potential of pure toluene.

2A. (25 points)

The triple point of ammonia is at a temperature of 195.41 K and a pressure of 0.0608 bar. If the enthalpy of vaporization for ammonia is 23.35 kJ mol^{-1}. What is the standard boiling temperature of ammonia?

$$\ln\left(\frac{1.013}{.0608}\right) = \frac{-23{,}350}{8.314}\left(\frac{1}{T_b} - \frac{1}{195.41}\right)$$

$$T_b = 243.0\ K$$

2B. (25 points)

What is the boiling point of a solution made of 100 mL of benzene and 5 g of anthracene

Benzene
M.W. = 78.11 g mol^{-1}
Density = 0.8765 g cm^{-3}
K_b= 2.53 °C m^{-1}
K_f = 4.3 °C m^{-1}
T_b = 80.1°C

Antracene
M.W. 178.23 g mol^{-1}

$$\Delta T = K_b m = (2.53)(.3125) = \sout{7.9K}\ +0.79K$$

$$\frac{5}{178.23} = 2.805 \cdot 10^{-2}\ mol$$

$$T_b = 80.1 + .7.9 = 80.9°C$$

$$(100\ mL \times)(.8765) = 87.65 g / 1000 g\ kg^{-1} = 8.765 \cdot 10^{-2}\ kg$$

$$m = \frac{2.805 \cdot 10^{-2}\ mol}{8.765 \cdot 10^{-2}\ kg} = .3.125\ m$$

3. (50 points)

You add 0.1 g of a protein to a make a solution with water (density 1 g cm^{-3}) that has a total volume of 100 mL. This solution has an osmotic pressure that is 0.02 bar at 25°C. What is the molecular weight of the protein? Estimate the vapor pressure of this solution at 25°C given the vapor pressure of pure water at that temperature is 25 Torr?

$$\Pi = [B]RT$$

$$[B] = \frac{\Pi}{RT} = \frac{0.02 \text{ bar}}{(0.08314 \text{ L-bar K}^{-1} \text{mol}^{-1})(298 \text{ K})}$$

$$[B] = 8.07 \cdot 10^{-4} \text{ M}$$

$$(8.07 \cdot 10^{-4} \text{ mol L}^{-1})(.1 \text{ L}) = 8.07 \cdot 10^{-5} \text{ mol}$$

$$MW = \frac{.1 \text{ g}}{8.07 \cdot 10^{-5} \text{ mol}} = \boxed{1240 \text{ g mol}^{-1}}$$

$$P_{H_2O} = X_{H_2O} P^*_{H_2O} = \frac{n_{H_2O}}{n_{protein} + n_{H_2O}} (25)$$

$$100 \text{ mL} \rightarrow 100 \text{ g} = 5.55 \text{ mol}$$

$$P_{H_2O} = \frac{5.55}{5.55 + 8.07 \cdot 10^{-5}} (25) \approx \boxed{25 \text{ Torr}}$$

4. (50 points)

A chunk of a pure substance with a molecular weight of 86 g mol^{-1} has a density of 1.532 g cm^{-3} at its melting point of 38.89°C and a pressure of 1 atm. When the pressure is raised to 25 atm the melting temperature increases to 39.59°C. Use this information and the thermodynamic information below to estimate the density of the liquid compound at the standard melting point.

$S°_M$ (solid) = 76.78 J mol^{-1} K^{-1}

$\Delta_{fus}H$ = 2.340 kJ mol^{-1} $= 2340 \text{ J mol}^{-1} = 23.11 \text{ L-atm}$

$$\text{slope} = \frac{\Delta P}{\Delta T} = \frac{\Delta H}{T \Delta V} \quad \frac{24 \text{ atm}}{0.74 \text{ K}} = 30.38 \text{ atm K}^{-1}$$

$$\Delta V = \frac{\Delta H}{T(\text{slope})} = \frac{23.11 \text{ L-atm mol}^{-1}}{(312 \text{ K})(30.38 \text{ atm K}^{-1})} = 2.438 \cdot 10^{-3} \text{ L mol}^{-1}$$

$$\Delta V = (2.438 \cdot 10^{-3} \text{ L mol}^{-1}) / (86 \text{ g mol}^{-1})$$

$$= 2.835 \cdot 10^{-5} \text{ L g}^{-1}$$

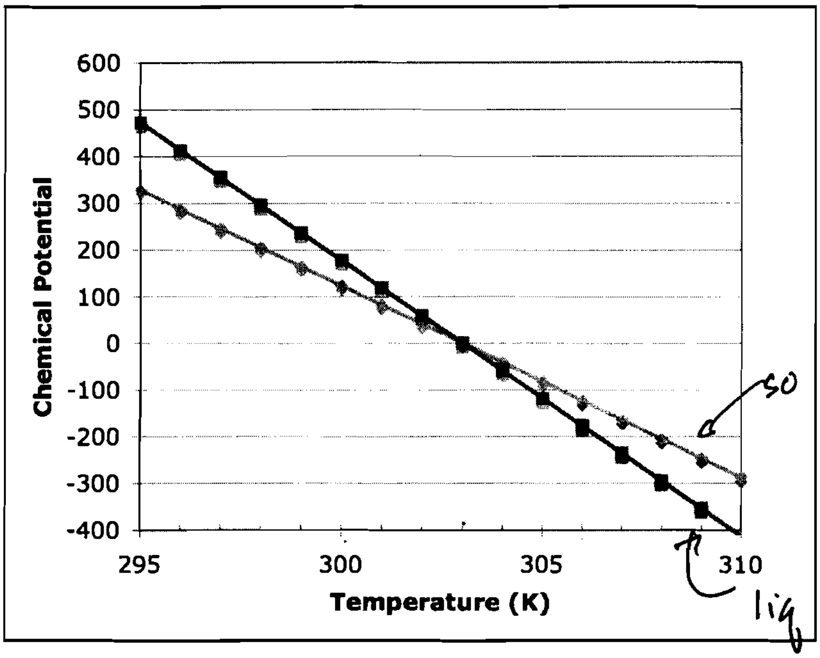
$$\Delta V = V_{liq} - V_{sol} \qquad V_{sol} = \frac{1}{1.532 \text{ g cm}^{-3}} = 6.527 \cdot 10^{-1} \text{ cm}^3 \text{ g}^{-1} = 6.527 \cdot 10^{-4} \text{ L g}^{-1}$$

$$2.835 \cdot 10^{-5} \text{ L g}^{-1} = V_{liq} - 6.527 \cdot 10^{-4} \text{ L g}^{-1}$$

$$V_{liq} = 6.811 \cdot 10^{-4} \text{ L g}^{-1} = 6.811 \cdot 10^{-1} \text{ cm}^3 \text{ g}^{-1}$$

$$\text{density} = \frac{1}{V} = \frac{1}{6.811 \cdot 10^{-1}} = \boxed{1.468 \text{ g cm}^{-3}}$$

(10 points) Don't waste anytime of this if you are not sure of how to figure it out.



The following is a graph of the chemical potential of solid and liquid Gallium as a function of temperature.

Given this graph what is the enthalpy of fusion for Gallium?

slope = $-S_m$

~~sli~~ $-S_{m\,liq} =$ ~~475 − (−400)~~ $\frac{-400-475}{15K} = -58.33\ J\,K^{-1}$

$-S_{m\,sol} = \frac{-300-325}{15} = -41.67\ J\,K^{-1}\,mol^{-1}$

$\Delta_{fus}S = 58.33 - 41.67 = 16.67\ J\,K^{-1}\,mol^{-1}$

$\Delta_{fus}H = T\Delta_{fus}S = (303\,K)(16.67) = 5.05\ kJ\,mol$