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CHEM 3410: Physical Chemistry I — Fall 2009

In-class practice problems

October 21, 2009

1. Antimony trioxide Sb_2O_3, has two structurally different crystalline forms: cubic and orthorhombic (ortho). Over a range of temperatures, the value of $\Delta\mu$ for the change in state

$$Sb_2O_3(ortho, p = 1\ bar, T) \rightarrow Sb_2O_3(cubic, p = 1\ bar, T)$$

is given by (in units of J, T in Kelvin, and with ΔC_p negligibly small):

$$\Delta\mu(T, p = 1bar) = -5,815. + 6.90T$$

   (a) Which form of Sb_2O_3 is thermodynamically stable at 298 K and 1 bar?

   (b) At what temperature are the two forms in equilibrium at p=1 bar?

   (c) The molar volumes of the cubic and orthorhombic forms are found to be $\overline{V}_{cubic} = 5.606 \times 10^{-5}\ m^3$ and $\overline{V}_{ortho} = 5.141 \times 10^{-5}\ m^3$. Using the Clapeyron equation, calculate the slope of the cubic-orthorhombic coexistence line ($\frac{dP}{dT}$) in units of bar/K.

   HINT: 1 J/m^3 = 10^{-5} bar and $\Delta\overline{S} = -\left(\frac{\partial\Delta\mu}{\partial T}\right)_P$.

2. You synthesize a new drug with the following properties:

   - The vapor pressure over the liquid phase (in bar) is given as:

$$\ln P_l = \frac{-3010}{T} + 13.2$$

   - The vapor pressure over the solid phase (in bar) is given as:

$$\ln P_s = \frac{-3820}{T} + 16.1$$

   (a) What is the temperature and pressure at the triple point?

   (b) Is the solid, liquid, or gas stable at $P = 1$ bar and $T = 298$ K?

   (c) Approximate $\Delta\overline{H}_{sublimation}$.

3. It has been suggested that the surface melting of ice plays a role in enabling speed skaters to achieve peak performance. Carry out the following calculation to test this hypothesis. At 1 atm pressure, ice melts at 273 K, $\Delta H_{fusion} = 6010$ J/ mol, the density of ice is 920 kg/m^3, and the density of liquid water is 997 kg/m^3. Also note that 1 bar = 10^5 Pa.

   (a) What pressure is required to lower the melting temperature by 5.0C?

   (b) Assume that the width of the skate in contact with the ice has been reduced by sharpening to 25×10^{-3} cm, and that the length of the contact area is 15 cm. If a skater of mass 85 kg is balanced on one skate, what pressure is exerted at the interface of the skate and the ice?

   (c) What is the melting point of ice under this pressure?

   (d) If the temperature of the ice is -5.0°C do you expect melting of the ice at the iceskate interface to occur?