

Problem Set 3  
3.20 MIT  
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Fall 2003

**Problem 1**

It is found that a certain liquid boils at a temperature of  $95^{\circ}\text{C}$  at the top of a hill, whereas it boils at a temperature of  $105^{\circ}\text{C}$  at the bottom. The latent heat is  $1000\text{ cal/mol}$ . What is the approximate height of the hill?

**Problem 2**

The boiling point of Li is  $1620\text{ K}$ .

- (a) What is the vapor pressure of liquid Li at  $1000\text{ K}$ ?
- (b) Estimate the melting point of lithium from the data given.

Data:

Enthalpy of evaporation is  $156\text{ kJ/mol}$

Vapor pressure above solid Li is given by:

$$\ln(P) = 13.049 - \frac{19,314}{T}$$

**Problem 3**

(a) A chamber at  $1500\text{ K}$  with a volume of one cubic meter contains one gram of Ag. What is the status of the silver in the chamber? Is it all vapor, all liquid, or part liquid and part vapor? If the latter, what fraction of the silver is in the vapor phase?

(b) How much heat is required to evaporate one mole of Ag from a very large quantity of a silver-copper liquid solution at  $1500\text{ K}$  containing  $x_{\text{Ag}} = 0.25$ . Assume the solution is ideal.

Data for Silver:

Melting point =  $1235\text{ K}$

Vapor pressure of liquid given by

$$\ln(P) = -\frac{30671}{T} + 12.5 \text{ [P in atm, T in K]}$$

Enthalpy of melting for Ag =  $11.3\text{ kJ/mol}$

Heat capacity for liquid Ag =  $33\text{ J/mol-K}$

**Problem 4**

A container kept at a constant temperature of  $70^{\circ}\text{C}$  (see figure) contains a small amount of liquid water. The total gas pressure in the container is  $1\text{ atm}$ . This gas phase consists of the water vapor in equilibrium with the liquid water and inert  $\text{N}_2$  gas. What is the total pressure in the container when the volume of the container is isothermally reduced to half of the original volume? You may assume that the liquid water takes up a negligible amount of volume. Also, you may neglect the effect of total pressure on the vapor pressure of water.

Data:

Enthalpy of evaporation for water at  $40^{\circ}\text{C}$  is  $43.54\text{ kJ/mol}$

Vapor pressure of water at  $70^{\circ}\text{C}$  is  $0.3\text{ atm}$



**Problem 5**

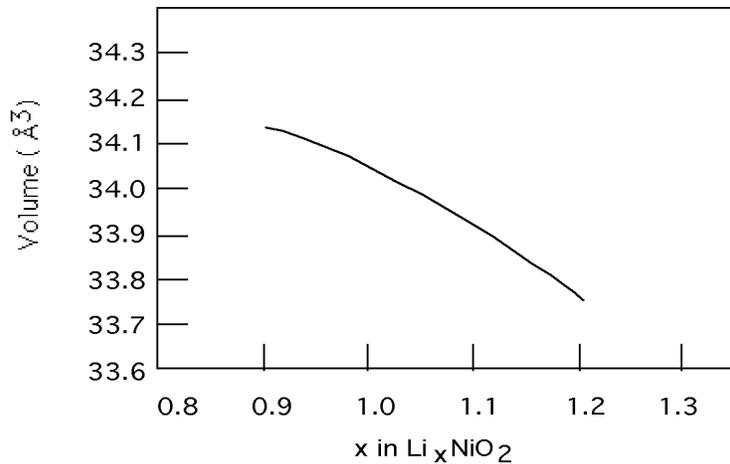
- (a) What is the vapor pressure of  $H_2O$  at  $100^\circ C$  (the boiling point of water) ?  
(b) The weather forecast tells me that it is  $59^\circ F$  ( $15^\circ C$ ) outside with a relative humidity of 65%. What is the dew point of that air?

Data:

Enthalpy of evaporation for  $H_2O$  at  $100^\circ C = 40.6 \text{ kJ/mol}$

**Problem 6**

Below is the volume of the unit cell of  $Li_xNiO_2$  as a function of  $x$ . When  $x$  increases Li is accommodated inside the unit cell of the material. What is the partial molar volume of Li in this material for  $x = 1$ ? Look carefully at what exactly this graph gives you!



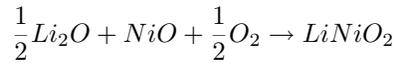
**Problem 7**

The vapor pressure of pure B at 1000 K is  $5 \times 10^{-4}$  atm. If B is in an ideal solution with another species at 1000 K, its vapor pressure will be:

- Higher than  $5 \times 10^{-4}$   
 Lower than  $5 \times 10^{-4}$   
 Equal to  $5 \times 10^{-4}$   
 Impossible to say

**Problem 8**

$\text{LiNiO}_2$  is an important material for rechargeable lithium batteries. It is made by reacting  $\text{Li}_2\text{O}$  and  $\text{NiO}$  in an oxygen atmosphere. The desired reaction is:



However, one finds that when synthesizing in air, the material always ends up being rich in Ni and deficient in Li, i.e. one ends up with  $\text{Li}_{1-x}\text{Ni}_{1+x}\text{O}_2$  where x is greater than zero.

What do you suggest to change the synthesis? Should  $P_{\text{O}_2}$  be increased or reduced from its value in air (0.21) to make more stoichiometric  $\text{Li}_{1-x}\text{Ni}_{1+x}\text{O}_2$ ? (i.e. make x smaller). Justify your answer briefly.

**Problem 9**

A long vertical column is closed at the bottom and open at the top; it is partially filled with a particular liquid and cooled to  $-5^\circ\text{C}$ . At this temperature the fluid solidifies below a particular level, remaining liquid above this level. If the temperature is further lowered to  $-5.2^\circ\text{C}$  the solid-liquid interface moves upward by  $40\text{cm}$ . The latent heat (per unit mass) is  $2\text{ cal/g}$  and the density of the liquid phase is  $1\text{g/cm}^3$ . Find the density of the solid phase. Neglect thermal expansion of all materials.

(Hint: Note that the pressure at the original position of the interface remains constant)

**Problem 10**

What is the maximum amount of water that can fall out of a standing air mass over the earth (per unit area)? To calculate, assume that all air is saturated with water. The temperature of the earth's surface may be taken as  $25^\circ\text{C}$  and the decrease of temperature with height is about  $6.5^\circ\text{C/km}$ . At  $25^\circ\text{C}$  the vapor pressure of water is  $3200\text{ Pa}$ . The enthalpy of boiling for water is about  $42\text{ kJ/mole}$ .