Chemistry 230
Problem Set # 6 — 10/1/99

Recommended Problems: 4.1-11, 4.13-16, 4.21-30, 4.33-47, 4.49, 4.50.

1. Problem 3.27 in Levine. Also,

   (a) Calculate how many people are needed in a group to ensure a probability of 0.9 that at least one of them has a birthday in September. (Assume months are equally probable for birthdays.)

   (b) For the coming election, how many people would have to be polled to give a "1% reliability" (standard deviation) for the results?

2. (a) The specific heat capacity of ice [$H_2O(s)$] at 1.00 atm is given precisely in the range –40 to 0˚C by

$$c_P\ (\text{cal g}^{-1}\text{K}^{-1}) = 0.5053 + 0.00186\ \theta\ ,$$

   where θ is the Celsius temperature. Calculate ΔH and ΔS for heating 20.00 g of ice from –40.00˚C to 0.00˚C at 1.00 atm.

   (b) Calculate ΔH and ΔS for heating 20.00 g of $H_2O(l)$ from 0.00˚C to 100.00˚C at P = 1.00 atm. The specific heat capacity of water may be taken as 1.0014 cal $g^{-1}K^{-1}$ over this temperature range.

   (c) Calculate ΔH and ΔS for heating 20.00 g of $H_2O(g)$ from 100.00˚C to 500.00˚C at P = 1.00 atm. The specific heat capacity of steam may be taken as 0.4799 cal $g^{-1}K^{-1}$ over this temperature range.

   (d) Calculate ΔH, ΔS, and ΔU for the conversion of 20.00 g of ice at –40.00˚C and 1.00 atm to steam at 500.00˚C and 0.600 atm. Treat $H_2O(g)$ as an ideal gas for this purpose, and use densities given in PS 4-2 where necessary. The specific heat of fusion for ice at its normal melting point is 79.72 cal/g, and the specific heat of vaporization at the normal boiling point is 542.3 cal/g.

3. (a) Calculate ΔA and ΔG for the two phase changes (at 1.00 atm) in Problem (2d).

   (b) Calculate ΔA and ΔG for the conversion of 20.00 g of ice at 1.00 atm and –10.0˚C to supercooled water at the same temperature and pressure. (Use your results from PS 5-2.)

4. A certain gas obeys the equation of state, $PV_m = RT\,(1+bP)$, where b is a constant. For this gas, obtain expressions for (a) $(\partial U/\partial V)_T$, (b) $C_{P,m} - C_{V,m}$, and (c) μ_{JT}. [All of thse should be reduced to forms containing R, P, and b only.]

5. 0.500 mol of a perfect gas is expanded adiabatically into vacuum (Joule experiment), with initial temperature 301 K, initial volume 5.00 L, and final volume 50.0 L. Calculate, if possible, q, w, ΔT, ΔV, ΔP, ΔU, ΔH, ΔS, ΔA, and ΔG for this process.

6. Now suppose the gas in the previous problem obeys the equation of state given in Problem 4, with b = 0.0010 atm^{-1}, and $C_{V,m} = {}^3/_2\, R$. Repeat the calculation of as many of the following as possible: q, w, ΔT, ΔV, ΔP, ΔU, ΔH.

7. In the phase transition, $CaCO_3$(*aragonite*) $\rightarrow$ $CaCO_3$(*calcite*), $\Delta G^\circ_{m,298}$ = –801 J/mol and $\Delta V^\circ_{m,298}$ = 2.75 cm^3/mol. At what pressure would aragonite become the stable form of $CaCO_3$ at 298 K?