Chemistry 230
Problem Set # 5 -- 9/22/99

Recommended Problems: 3.1-3, 3.5, 3.7, 3.9-11, 3.15, 3.21, 3.24, 3.29–3.32, 3.35, 3.38–3.40.

1. A sample of a perfect gas is expanded adiabatically and reversibly from P_1 to P_2 ($P_1 > P_2$). Assume that $C_{V,\text{m}}$ is constant, and
   (a) Obtain an expression relating the initial and final temperatures, T_1 and T_2, to P_1 and P_2 for this process.
   (b) Take $C_{V,\text{m}}$ to be $^3/_2 R$, P_1 = 20.0 atm, P_2 = 1.00 atm. If the initial temperature is 27˚C, what is the final temperature in such an expansion?
   (c) Calculate q, w, ΔU, ΔH, and ΔS for such an expansion of 1.27 mol of perfect gas.

2. Problem 3.14. Also calculate ΔH and ΔU for the process.

3. Continuing with the theme in the preceding problem, note that the initial state (supercooled water) is *metastable*. Adding a tiny crystal of ice will stimulate the system toward true equilibrium, which will be either a mixture of ice and water at 0˚C, or all ice at some temperature slightly below 0˚C. Assume this process occurs in an insulated container (*i.e.*, adiabatically) at a fixed pressure of 1.00 atm. (a) What is ΔH for this process? (b) Use your answer in (a) to determine the final equilibrium state. (c) Calculate ΔS for the process? (d) What (approximately) is ΔS_{univ} for this process?

4. 20.0 g of H_2O at 1.00 atm and 98˚C is mixed with 60.0 g of H_2O at 1.00 atm and 2˚C, in a perfectly insulated vessel. The density and heat capacity of water may be taken as 1.00 g/cm^3 and 18.0 cal K^{-1} mol^{-1}. [**Hint:** See problem 3.16 in Levine.]
   (a) Calculate the final temperature of the water.
   (b) Calculate ΔU, ΔH, and ΔS for this process.
   (c) Is this a reversible process?
   (d) What is ΔS_{univ} for this process?

5. 17.3 g of He at 48˚C and 1.35 atm is mixed with 27.5 g of Ar at 48˚C and 0.95 atm, the mixture finally being brought to a pressure of 1.00 atm (still at 48˚C). Treating the gases as perfect gases,
   (a) Calculate the numbers of moles of the two components and their mole fractions in the mixture.
   (b) Calculate the initial volumes for the two gases separately, and the final volume for the mixture.
   (c) Calculate ΔU, ΔH, and ΔS for the mixing process.

   [**Hint:** See Problem 3.17 in Levine.]

6. 9.43 mol of perfect gas having $C_{V,\text{m}} = {}^5/_2 R$ is held by a piston under a pressure of 40.0 atm at T = 299 K. The *external* pressure P_{ext} is *suddenly* reduced to 10.0 atm, and the gas expands adiabatically and irreversibly. [**Hint:** Recall Problem 2.19, which deals with w for an irreversible expansion.]
   (a) Calculate the final T of the gas (after the piston stops oscillating and equilibrium is established).
   (b) Calculate q, w, ΔU, ΔH, and ΔS for this process.
   (c) What is ΔS_{univ} for this process?

7. Continuing with the previous problem, suppose now that the heat capacity is <u>temperature dependent</u>, $C_{V,\text{m}} = 18.8 + 0.021\,T$ (J K^{-1} mol^{-1}). Repeat the determination of ΔT and the calculation of q, w, ΔU, ΔH, and ΔS.