ECHE 363 – Thermodynamics of Chemical Systems
Homework #4

100 points total. Complete the following problems and upload your solutions to the Canvas assignment dropbox by the due date/time.

You are strongly encouraged to collaborate with your classmates on the homework, but each student is required to come up with a unique solution to the homework problems. For full credit, you must show all work. This includes showing all steps involving algebra and/or calculus. Your calculator can only be used for the final evaluation of numerical answers and may not be used for solving algebraic equations and/or integrals.

1. Develop a general expression for Δs_m for an ideal gas that goes from (P_1, T_1) to (P_2, T_2), where the heat capacity is given by:

$$\frac{c_{p,m}}{R} = A + BT + CT^2 + \frac{D}{T}$$

   where A, B, and C are constants.

2. Calculate the change in entropy for the system for each of the following cases. Explain the sign that you obtain by physical argument.

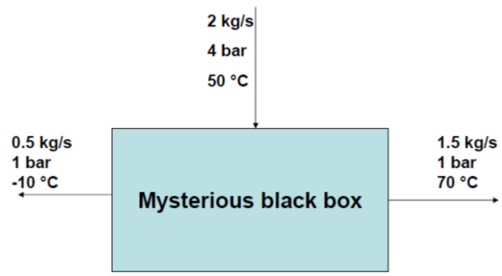
   a. A gas undergoes a reversible, adiabatic expansion from an initial state at 500 K, 1 MPa, and 8.314 L to a final volume of 16.628 L.

   b. One mole of methane vapor is condensed at its boiling point, 111 K; $\Delta h_{v,m}$ = 8.2 kJ/mol.

   c. One mole of liquid from 100 °C to 0 °C. Take the average heat capacity of water to be 4.2 J/g-K.

   d. Two blocks of the same metal with equal mass are at different temperatures, 200 °C and 100 °C. These blocks are brought together and allowed to come to the same temperature. Assume that these blocks are isolated from their surroundings. The average heat capacity of the metal is 24 J/mol-K.

3. A fast-talking salesperson comes to your doorstep and says she is down on her luck and is willing to sell you the patent rights to her most glorious invention. She brings out a mysterious black box and says it can take an inlet stream of ideal gas at 2 kg/s and 4 bar and cool part of it (0.5 kg/s) from 50 °C to –10 °C with no external parts, as shown below.



You are feeling somewhat adventurous and are tempted by this offer, but must ask the fundamental question: "Can it work?" Can it? Explain. If necessary, you may assume that the system is adiabatic.

4. What is the minimum amount of work required to separate an inlet stream of air flowing at 20 °C and 1 bar into exit streams of pure O_2 and N_2 at 20 °C and 1 bar? Assume that air has 20% O_2 and 80% N_2.

5. A steam turbine in a small electric power plant is designed to accept 4500 kg/hr of steam at 60 bar and 500 °C and exhaust the steam at 10 bar.

   a. Assuming that this turbine is adiabatic and generates the maximum possible power, compute the exit temperature of the steam and the power generated by the turbine.

   b. The efficiency of a turbine is defined to be the ratio of the work actually obtained from the turbine to the work that would be obtained if the turbine operated isentropically between the same inlet and exit pressures. If the turbine in (a) is adiabatic but only 80% efficient, what would be the exit temperature of the steam? At what rate would entropy be generated within the turbine?

6. A portable power supply consists of a 28 L bottle of compressed helium, charged to 13.8 MPa at 300 K, connected to a small turbine. During the operation, the helium drives the turbine continuously until the pressure in the bottle drops to 0.69 MPa. The turbine exhausts at 0.1 MPa. Neglecting heat transfer, calculate the maximum possible work from the turbine. Assume helium to be an ideal gas with $c_{p,m}$ = 20.9 J/mol-K.

7. Answer the following reflection questions (5 points):

    a. What about the way this class is taught is helping your learning?

    b. What about the way this class is taught is inhibiting your learning?