ECHE 363 – Thermodynamics of Chemical Systems
Homework #1

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. The state function f is a function of two independent variables x and y; i.e., $f = f(x, y)$. You wish to evaluate the change in the function (Δf) as the independent variables are changed from (x_1, y_1) to (x_2, y_2), where x_1, x_2, y_1, and y_2 are specific values of the independent variables of the function.

   The function $f(x, y)$ also has the following total differential:

$$df = \left(A + Bx + Cx^2\right) dx + \frac{D}{y} dy$$

   where A, B, C, and D are all constants independent of x and y.

   Given that $f(x, y)$ is a state function with the above total differential, evaluate the following:

   a. $\left(\frac{\partial f}{\partial x}\right)_y$

   b. $\left(\frac{\partial f}{\partial y}\right)_x$

   c. $\Delta f = f\left(x_2, y_2\right) - f\left(x_1, y_1\right)$

2. For each of the following cases, draw a picture of the system being described and list as many properties of the equilibrium state as you can, especially the constraints placed on the equilibrium state by its surroundings. Be sure to label the system in your schematics.

    a. The system is placed in thermal contact with a thermostatic bath maintained at temperature T.

    b. The system is placed in a rigid container and thermally and mechanically isolated from its surroundings.

    c. The system is contained in a frictionless piston–cylinder assembly that is exposed to an atmosphere at pressure P and thermally isolated from its surroundings.

    d. The system is contained in a frictionless piston–cylinder assembly that is exposed to an atmosphere at pressure P and is in thermal contact with an thermostatic bath maintained at temperature T.

    e. The system consists of two insulated tanks of gas connected by tubing. A valve between the two tanks is fully opened for a short period of time and then closed. When the valve is closed, it is well-insulated. (Note: Think through carefully about the consequences of the tank being opened for a short time *vs.* a long time – what would the difference be in the properties of the gas in the two tanks?)

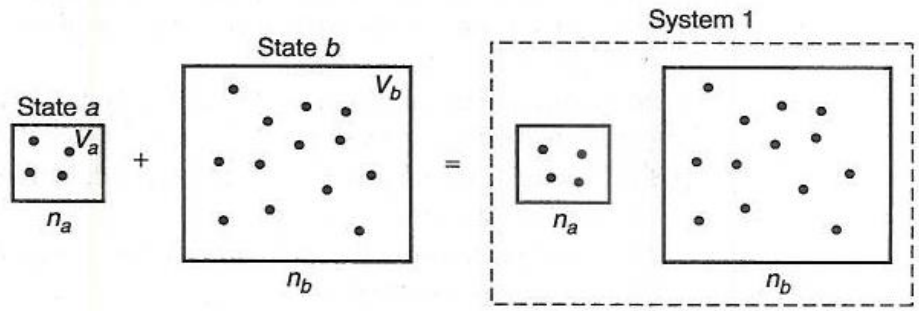
3. When a system contains regions that differ in physical structure or chemical composition, an overall value can be assigned to its properties. Consider the system, "System 1", shown below (note that "a" and "b" can be considered to be touching in System 1). It contains n_a molecules in state "a" and n_b molecules in state "b".

    a. Develop an expression for the extensive volume V_1 of System 1 in terms of n_a, n_b, and the volumes of each homogeneous region V_a and V_b.

    b. Develop an expression for the intensive molar volume $v_{m,1}$ in terms of n_a, n_b, and the molar volumes of each homogeneous region $v_{m,a}$ and $v_{m,b}$.

    c. Generalize the result of (a) to come up with an expression for any extensive property K_1 in terms of n_a, n_b, and the extensive properties K_a and K_b.

    d. Generalize the result of (b) to come up with an expression for any intensive property $k_{m,1}$ in terms of n_a, n_b, and the intensive properties $k_{m,a}$ and $k_{m,b}$.



4. What size vessel holds 2 kg water at 1 bar such that 45% is vapor? What are the pressure and entropy (S)? <u>*Note*</u>: although we have not talked extensively about entropy in class, you may simply look up values of S on the steam tables for this and related problems on this assignment.

5. Determine the temperature, quality, and internal energy (U) of 4 kg of water in a rigid container of volume 1 m^3 at a pressure of 1.6 bar.

6. Three kg of saturated liquid water are evaporated at 60 °C.

    a. At what pressure will this occur at equilibrium?

    b. What is the initial volume?

    c. What is the system volume when 2 kg have evaporated? At this point, what is ΔU relative to the initial state?

d. What are ΔH and ΔU relative to the initial state for the process when all 3 kg have been evaporated?

e. Make a qualitative sketch of parts b–d on a Pv_m diagram, labeling the states before, during, and after evaporation.

7. 2 kg of water exist initially as a vapor and a liquid at 90 °C in a rigid container with volume 2.42 m^3.

   a. At what pressure is the system?

   b. What is the quality of the steam?

   c. The temperature of the container is raised to 100 °C. What is the quality of the steam and what is the pressure? What are ΔU and ΔH at this point relative to the initial state?

8. 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?

   c. So far, we've had a brief math/calculus review, discussed different types and sources of thermodynamic properties, and solved problems involving steam quality. Is there anything you still find confusing about these or related concepts?