ECHE 260: Intro to Chemical Systems

Homework #5A (50 points)

Conceptual Questions (12 points):

1. (3 points) Water is in equilibrium at 50°C with air in a piston-cylinder system. The total pressure is 1 bar. The pressure is raised to 2 bar by pushing down on the piston at constant temperature. At the new equilibrium, the partial pressure of the water _____.
    a. Increases
    b. Remains the same
    c. Decreases

2. (3 points) A piston-cylinder (variable volume container) contains superheated propane. Construct a plot (you can draw it by hand) with the partial pressure of propane on the y-axis and temperature on the x-axis. Then, draw a line that describes the how the partial pressure of propane changes during cooling. *Justify you answer, it may be useful to label key temperatures on the plot.*

3. (3 points) A pure stream of saturated acetone vapor is fed to a furnace. The acetone vapor has a temperature of 80^{o}C. What is the vapor pressure of the stream?

4. (3 points) Consider two different continuous, steady state partial condensers operating at equilibrium conditions. The feed to condenser #1 is a mixture of two gases (A and B) and the condensate is pure B. The feed to condenser #2 is a mixture of two gases (C and D) and the condensate contains a mixture of C and D. The vapor phase contains pure C. Which of the following statements is true? Circle all that apply.
    a. $P_B=P_B^{sat}$
    b. $P_A=P_A^{sat}$
    c. $P_C=P_C^{sat}$
    d. $P_D=P_D^{sat}$

Quantitative Question (35 points)

5. **Ammonia production.** Ammonia, which is a commodity chemical used in the production of fertilizers and cleaning products, is produced according to this chemical reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

During ammonia synthesis the reaction does not go to completion, therefore the stream exiting the reactor (effluent) is a mixture of nitrogen, hydrogen and ammonia. The effluent leaves the reactor at 430K, 170 atm and contains 60 mol% ammonia, 30 mol% hydrogen and the rest in nitrogen. The reactor effluent is fed to a partial condenser operating at steady state which liquefies the ammonia and operates at -50°C. Only 20% of the ammonia fed to the system is liquefied and the volumetric flowrate of the reactor effluent is 1.4 L/s. What is the operating pressure of the condenser (atm)? What is the composition of the vapor phase leaving the condenser? What is the volumetric flowrate of the liquid ammonia (L/s)?

e. (10 points) Draw and fully label a process flow diagram. Remember for VLE sub-units, all streams require T and P. Write all additional information from the problem statement as algebraic expressions using variables from your PFD. Identify the quantities you want to solve for.

f. (5 points) Perform a DOF analysis. Clearly identify the process variables associated with your analysis. Based on your DOF analysis, outline the order in which you would solve the subsystems to answer the questions in the problem statement.

g. (10 points) Write out your problem solving procedure which should include: (1) all relevant material balances and other equations that you would need for each sub-system according to your outline in part b and (2) description of how you would solve them.

h. (5 points) Solve for a numerical answer.

i. (5 points) How could you adjust the operating conditions of the condenser to increase the percent of ammonia liquefied in the process?

Reflection (3 points)

1. **(3 points)** We have now finished material balances on non-reactive processes, single phase systems/equations of state and multiphase systems/vapor-liquid equilibrium.
   a. Is there anything you still find confusing about the course content (units 1-5)?
   b. How did you prepare for quiz 1?
   c. How do you plan to prepare for quiz 2?