ECHE 260: Intro to Chemical Systems

Homework #6 (50 points)

Conceptual Questions (15 points)

1. (5 points) Consider two separate, open systems. In the first system, pure liquid octane is flowing through a pipe. In the second system, pure saturated octane vapor is flowing through a pipe. If they are at the same temperature and pressure, specific enthalpy of the superheated octane is _____ the specific enthalpy of liquid octane. Justify your answer.
    a. Greater than
    b. Less than
    c. Equal to

2. (10 points) Write a hypothetical process path for the real process path shown below. Write each hypothetical step, describe each transition (e.g. constant T, constant phase, change in P). You do not need to include any equations or calculations; however, your path should be written such that you can use data from Table B.1 or Table B.2 to calculate the change in specific enthalpy of the process.

    Cyclopentane (T_1, P_1, liquid) → Cyclopentane (T_2, P_2, gas)

Quantitative Questions (30 points)

3. (**30 points**) Formaldehyde is used as a precursor in the production of adhesive products like PostIt™ notes and double-sided tape. It is produced from the reaction of methane and oxygen in the presence of a catalyst. After the reaction, the formaldehyde is purified by passing the reactor effluent through two condensers. The first condenser removes water, and the second condenser removes formaldehyde.

$$CH_4\,(g) + O_2\,(g) \rightarrow CH_2O(g) + H_2O\,(g)$$

In a continuous, steady state process, a gaseous mixture containing the following species exits the reactor at 600 K and 2 atm: oxygen at 4 mol/min, formaldehyde at 10 mol/min, and 2 mol/min water vapor. The reactor effluent is fed to the first condenser which operates at a pressure of 1.1 atm and 0 °C. All of the water is removed from the vapor phase and exits condenser 1 as a pure water stream. Then, the remaining oxygen and formaldehyde from the first condenser are sent to a second condenser 2 which operates at -40 °C and 1.2 atm. The liquid product stream from condenser 2 contains pure formaldehyde. Inside condenser 2, the formaldehyde is the only species in vapor-liquid equilibrium. What is the rate at which heat must be removed from the second condenser (kJ/min)? The heat capacity of liquid formaldehyde is 105 kJ/(mol °C).

A) Draw and fully label a process flow diagram (PFD)

B) Write the material balances and describe how you would solve for all relevant molar flowrates.
C) Write the first law of thermodynamics, cancel terms, and justify why. The final form of the equation should be written in terms of process variables from your PFD.
D) Draw the hypothetical path for each species and write the relevant equations to calculated enthalpies for each theoretical process step. Identify the reference state for each species and look up all necessary values.
E) Explain how you would solve for the rate of heating (kJ/min).

Reflection (5 points)

4. Are there any concepts regarding energy balances (reactive and non-reactive) that you still find confusing?
5. Are there are concepts regarding material balances (reactive and non-reactive) that you still find confusing?