ChE 201 – Spring 2002 – Final Exam – 200 pts

No notes or textbooks – Don't write on the pink sheets

Except for Question 1, use only the "A" term in the equation for C_p

Question 1 (30 points)

The heat capacity of gas phase cumene at 20 ºC is 0.1498 kJ/mol ºC. The heat capacity of gas phase cumene at 150 ºC is 0.2113 kJ/mol ºC.

a. Using these data, find an equation that describes the heat capacity of cumene as a function of temperature.

b. Plot the equation that describes the heat capacity of cumene as a function of temperature on a graph. Be sure to label the axes.

c. Use your equation to find the change in specific enthalpy when cumene is heated from 40 ºC to 100 ºC.

d. Indicate the change in specific enthalpy when cumene is heated from 40 ºC to 100 ºC on your graph from part b.

Question 2 (30 points)

A company advertises an efficient new catalytic reactor system for partially oxidizing ethane to ethanol. The reactor consists of solid spheres (the catalyst) packed into a cylindrical tower, and has a temperature control system to hold the reactor temperature at a constant 70 °C. Air and ethane are fed to the bottom of the reactor. The company explains that this reactor is efficient because it does the reaction and separation simultaneously. Since the reaction temperature is below the boiling point of ethanol, the liquid ethanol product will continuously run out the bottom of the reactor while the unreacted gas phase species go out the top. Explain why this reactor cannot work as advertised. (15 points will be given for a complete and correct explanation that is purely qualitative, but a perfect answer will also include a quantitative demonstration of the ridiculousness of the claim.)

Question 3 (50 points)

A boiler is used to produce steam as a utility for a manufacturing process. The fuel for the boiler is 95 % methane and 5 % ethane at 30 °C. Assume complete combustion to CO_2 and H_2O. Air is fed to the boiler at 25 °C and in 25 % excess. Stack gases leave the boiler at 500 °C. The boiler produces saturated steam at 10.0 bar. After the steam circulates through the process, it returns to the boiler as liquid water at 150 °C to be reheated.

a. How much energy must be transferred in the boiler to produce 1 kg of steam?

b. If the steam is used to turn a turbine, what is the maximum amount of work that can be obtained per kg of steam?

c. Suppose that steam leaves the boiler with a velocity of 350 m/s and returns to the boiler with a velocity of 5 m/s. Estimate the error introduced into your answer to part a because of the assumption that changes in kinetic energy are negligible.

Question 4 (90 points)

A catalytic reactor is used to convert n-hexane to unsaturated hydrocarbons that can be used as feedstocks for other processes. Two competing reactions take place, the first making only ethylene and hydrogen, the second making ethylene, 1-butene and hydrogen. (Assume that the heat capacity of 1-butene is the same as the heat capacity of isobutene.)

$$C_6H_{14} \rightarrow 3\ C_2H_4 + H_2$$

$$C_6H_{14} \rightarrow C_2H_4 + C_4H_8 + H_2$$

n-Hexane is fed to the reactor at 25 °C. The reaction takes place at 400 °C. In the reactor, 95 % of the n-hexane is converted to products. Of the n-hexane that reacts, 40 % goes by the first reaction and 60 % by the second. For a basis of 100 moles of n-hexane fed,

a. Determine the amount of heat that must be transferred to maintain the reactor temperature.

b. State whether that heat should be added to or removed from the reactor.

c. State whether the reactor temperature would be higher or lower than 25 °C if the reactor were adiabatic.