Chemical Engineering 140 **September 30, 2009**

Midterm Examination #1

(155) 1. A dilute liquid species A reacts irreversibly and isothermally to species P according to first kinetics with rate constant k in a steady continuous stirred tank reactor (CSTR). The volume of the reactor is V, inlet and outlet volumetric flow rates are equal and constant at Q, and the inlet concentration of A is C_{Ain}. To increase the conversion of A, two options are proposed. First, a second CSTR of the same volume is placed in series with the first reactor, as illustrated in Figure 1. Concentrations and flows are listed on the figure.

Figure 1. Two CSTS in Series

A second suggested option to increase conversion is to return part of the exit flow (i.e., αQ) from the reactor back to the inlet line, as illustrated in Figure 2. This configuration is called recycle.

Figure 2. CSTR with Recycle

(10) a. Explain physically why two CSTRs in series increase the overall conversion of A

(10) b. Explain physically why a single CSTR with recycle increases the overall conversion of A

(25) c. Using steady-state species mass balances, find the expression for the conversion in Tank 1 of Figure 1.

(25) d. Using steady-state species mass balances, find the expression for the conversion in Tank 2 of Figure 1 (based on the inlet feed to Tank 2).

(10) e. What is the expression for the overall conversion of the two series CSTRs in Figure 1?

(40) f. Using steady-state species mass balances, find the expression for the overall conversion of the single CSTR with recycle in Figure 2

(15) g. Given a residence time in each CSTR of EMBED Equation.DSMT4 such that EMBED Equation.DSMT4 , which configuration of reactors gives the highest overall conversion? That is, does reactor configuration in Figure 1 or Figure 2 yield higher overall conversion and by how much? Explain why.

(20). h. Assume that the two series CSTRs in Figure 1 initially have no reactant in either reactor. Fluid flows and tank filling are, however, fixed. Species A is then injected into Tank 1 at concentration C_{Ain}. Write the necessary relations and initial conditions to solve for the startup of the two reactors. DO NOT SOLVE these equations.

(90) 2. Provide answers to the following short questions.

(10) a. For question 1 above (the CSTR problem), list and justify three assumptions.

(10) b. Explain the concept of volatility. What example was given in class?

(10) c. Explain the MAIN reason that methane is preferred over coal to fuel electric power generation.

(10) d. Explain under what circumstances you cannot assume conservation of moles.

(15) f. For a first-order irreversible reaction, why is conversion in a CSTR less than that in a
BSTR at equivalent residence times.

(25) g. A steady reactor has two inlet streams and one outlet stream. Inlet stream 1 has a flow of F=100 kg/hr with species A = 40 mol % and species B = 60 mol %. Inlet stream 2 contains only species C. In the outlet stream, species C = 50 mol % mol. In the reactor, A+B+C-> D with a conversion of A = 40 %. What is DoF for this system?

Q, C_{Ain}

Q,C_{A1}

Tank 1
V

Tank 2
V

∞

∞

Q, C_{A2}

Tank 1
V

$\alpha Q, C_{A1}$

∞

Q, C_{Ain}

$(1-\alpha)Q, C_{A1}$