10.37 Problem Set 4 Due March 7, 2007

Problem 1:

Biodiesel@MIT is working to convert the waste cooking oils from local dining halls and restaurants into diesel fuel to run the MIT shuttle buses.

Waste cooking oils can be converted to biodiesel in several ways. One way is by gas-phase pyrolysis:

$$(RC(O)OCH_2)_3 \rightarrow (RCH_2)_3 + 3\ CO_2$$

This can be modeled as first-order irreversible reaction with a measured $k=5\times10^{-3}\ min^{-1}$ at 150 C and a measured Ea=85 kJ/mole.

Pure cooking oil is injected into a hot (T=227 C) reactor at a rate of 2.5 mole/min. At this temperature all the species are in the vapor phase. The steady-state pressure in the reactor is 10 atm.

(a) If the reactor is a CSTR, what reactor volume is required to achieve 90% conversion?
(b) If the reactor is a PFR and the pressure drop is negligible, what reactor volume is required to achieve 90% conversion?
(c) If you had a PFR half the volume you computed in part (b), and then fed its output into a CSTR half the volume you computed in part (a), what would the conversion be? What if you hooked them up the other way round: the half-size CSTR first and the half-size PFR afterwards?

Suppose the reaction is carried out in a batch reactor, by filling it with enough cooking oil and heating rapidly to 227 C, so that when the oil all vaporizes, but before any significant reaction has occurred, the initial pressure in the reactor will be 2.7 atm.

(d) What will the pressure be in the isothermal batch reactor when the reaction has run to 90% conversion?
(e) What would the batch reactor volume have to be if we were to process 3600 moles/day (= 2.5 moles/minute) of cooking oil this way? Assume that the batch reactor can be emptied and refilled very rapidly, and that it is not necessary to clean the reactor between batches.
(f) Which reactor (CSTR, PFR, batch) would you recommend be used for this process? Explain briefly.

Problem 2: Do Fogler problem 4-19 parts (a) through (e). This problem is about a microreactor constructed by our new Department Head and some of his former graduate students.

For part (c), does the pressure ratio profile for the new particle diameter make physical sense? Why or why not? Decrease G (superficial mass velocity) to 3.5 kg/(m^2*s) and re-plot the molar flow rates, X (conversion) and y (pressure ratio). Does the pressure ratio make physical sense? Turn in plots for both cases (original G and new G).

For part (d), use Kc = 0.03 m^3/mol.

Print out hard copies of all Matlab programs, and all figures, and staple them to your handwritten solutions. Submit your Matlab programs to the 10.37 course website.