Name ________________________________ Student Number ___________

UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION

CHE333S - REACTOR DESIGN

APRIL 27, 2001

Exam Type: C

APPROVED PROGRAMMABLE AND NON-PROGRAMMABLE CALCULATORS ONLY

Examiner: B.A. Saville

DO ALL QUESTIONS

Question	Value	Grade
1	25	
2	25	
3	25	
4	25	
Total	100	

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1. A reactor is to be designed for a liquid phase reaction A + 2B → C. The reaction is first order with respect to each reactant, with a rate constant of 0.075 L mol^{-1} min^{-1}, and occurs isothermally and isobarically. The feed contains A at 0.50 mol/L, and B at 1.0 mol/L.

a) Determine the time required to obtain 75% conversion of A.

b) Determine the vessel volume required to produce 240 mol of C per day, if the plant operates 24 hours per day, and the down time is 20 minutes.

c) As an alternative to the batch reactor designed in parts (a) and (b), a PFR was considered in the event continuous operation was feasible. What is the residence time required for a PFR to achieve the same conversion as in (a)?

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2. A reactor must be designed for a gas phase reaction $C_2H_6 \rightarrow C_2H_4 + H_2$. The reaction is first order with respect to C_2H_6, with a rate constant of 0.534 s^{-1}. The feed contains 0.25 mol/L of C_2H_6, at 25 L/s.

a) Determine the vessel volume required for 80% conversion, if a single CSTR is used.

b) Determine the total vessel volume required for 80% conversion, if two equal-sized CSTRs are used.

c) Would the volume of a PFR be larger than, smaller than or the same as the volumes calculated in (a) and (b). Explain and JUSTIFY without calculations.

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3. An SO_2 converter is to be designed for a multistage unit to produce SO_3. The feed contains 9.5 mol% SO_2, 11.5% O_2, 79% N_2, and a trace of SO_3 at 100 kPa and 430°C. The feed rate of SO_2 is 120 mol/s, and 1.25×10^{-3} mol/s SO_3. The reaction occurs adiabatically and isobarically; the reaction enthalpy (ΔH_R) for this exothermic process is -100 kJ/(mol SO_2). Estimate the catalyst mass and bed volume required for the first stage of this unit, given that 60% conversion is obtained in this stage. Use a step size of 0.20 for the fractional conversion.

Data:

$K_p = 8 \times 10^{-5}$ EXP(12,100/T) MPa$^{-1/2}$

$$(-r_{SO_2}) = k_{SO_2}\left(\frac{p_{SO_2}}{p_{SO_3}}\right)^{1/2}\left[p_{O_2} - \left(\frac{p_{SO_3}}{p_{SO_2}K_p}\right)^2\right]$$

$k_{SO2} = 1.8 \times 10^{11}$ EXP(-26000/T) mol s^{-1} MPa^{-1} (g cat)$^{-1}$

$c_P = 0.94$ J g^{-1} K^{-1}. Molar masses for S, O, and N are 32, 16, and 14 g/mol, respectively.

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4. Kinetics experiments were conducted using two different sizes of spherical pellets. The gas-phase reaction is 1st order; in each test, the concentration of the reactant A was kept constant at 0.025 mol/L. A separate study established that the effective diffusivity, D_e, was 2.5×10^{-5} cm²/s. The following data were obtained from the kinetics experiments:

$(-r_A)_{obs}$, moles of A L^{-1} s^{-1}	1.46×10^{-3}	8.6×10^{-4}
particle radius, cm	0.060	0.12

a) Determine the Thiele Modulus (ϕ') and effectiveness factor for each particle
b) Determine the intrinsic reaction rate and rate constant for the intrinsic reaction (k_A)

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