**PRINCE OF SONGKLA UNIVERSITY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CHEMICAL ENGINEERING**

Final Examination : Semester I — Academic year : 2007

Date : October 5th, 2007 — Time : 9.00 – 12.00, Room : R201

Subject : 231-321 Chemical Engineering Kinetics & Reaction Design I

*ทุจริตในการสอบ โทษขั้นต่ำปรับตกในรายวิชานั้น หรือ พักการเรียน*
*1 ภาคการศึกษา และ โทษสูงสุดคือ ให้ออก*

**Rules;**

1. All book, class material and every model of calculators are allowed.
2. You can assume any parameter you need for solving each problem. (However, the exam should already give you everything)
   ท่านสามารถสมมติค่าขึ้นมาได้เพื่อประกอบการคำนวณแต่อย่างไรก็ตามข้อสอบนี้ได้บอกท่านทุกอย่างเพื่อใช้หาคำตอบ โดยไม่ต้องสมมติค่าใดๆ แล้ว

**Name**.........................................................................................................

**Student ID**..........................................

| Problem | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|
| **Point** | **30** | **30** | **45** | **25** | **15** | **35** | **180** |
| **You made** | | | | | | | |

**There are 6 problems in 12 pages including this page.**

**Let's check it up before working on it.**

**Wish you BEST OF LUCK!**

Pim-pahn Kiatsimkul

Chemical Engineering, PSU

September 26th, 2007

Student ID....................................................

**Problem 1** (30 points) The following table shows raw data from an experiment of producing **C** from a liquid-phase reaction of **A** and **B**. The reaction was carried out in a constant-volume batch reactor at a constant temperature.

| Time (min) | $C_A$ (mol/liter) |
|---|---|
| 0 | 0.49 |
| 10 | 0.30 |
| 20 | 0.22 |
| 30 | 0.18 |
| 50 | 0.155 |
| 80 | 0.135 |

**A + B → C**

When $C_{B0}$=5 mol/dm$^3$

a) (5 points) Show that the reaction is not zero order with respect to **A**.

b) (15 points) Show that the reaction is said to be second order with respect to **A** and calculate k' (reaction constant rate when $C_B$ is a constant)

c) (10 points) Find k (reaction constant rate) and rate law when the reaction order with respect to **B** was found to be first order.

**There is NO POINT for any graph. I only care for data that you use in your plot.

**Problem 2** (30 points) Write down the right answer as best you can.

a) (3 points) Why should not we reduce $\Delta P$ by increasing cross section area of PBRs?

b) (5 points) What type of reactor has a high ratio of surface area to volume. And what is good about it?

c) (5 points) Do you think $\Delta P$ is more significant in gas phase reaction or liquid phase reaction and why?

d) (5 points) Consider a gas-phase reaction operated in a plug flow membrane reactor.

$$A \rightarrow B + C$$

The reaction conversion is high when compound **B** is separated from the reactor by membrane.

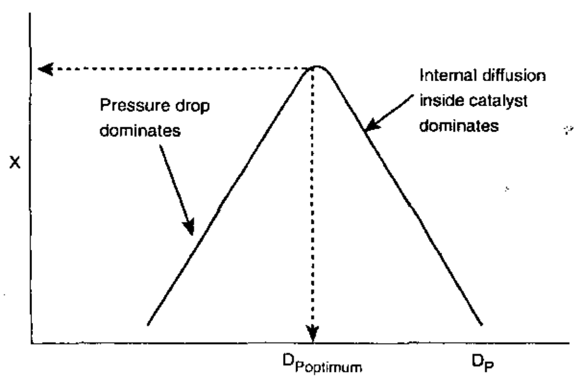
So, Permeate is compound .........-rich stream.

Effluent is compound .............-rich stream.

How would the membrane increase the reaction conversion?

e) (5 points) How does the rule of thumb of Damköhler number say for continuous flow reactors? And how is it useful?

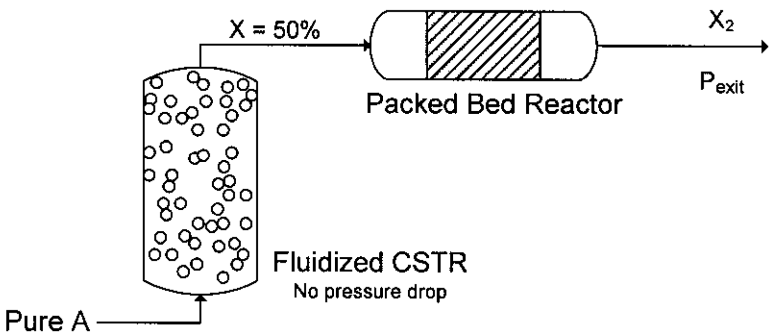
g) (7 points) Explain this graph and what can you find from it?



**Problem 3** (45 points) A gas-phase reaction (A → B) is carried out isothermally in a fluidized catalytic CSTR containing 50 kg of catalyst. The reaction rate law was found to be $-r'_A = kP_A$ where $P_A$ is a partial pressure of **A.**

Pure **A** is fed to the reactor at 20 atm. There is virtually no pressure drop in the CSTR. Product stream from the CSTR has X=0.5. It is proposed to put a PBR containing the same catalyst weight in series with the CSTR. The pressure drop parameter for the PBR is $\alpha$ = 0.018 $kg^{-1}$.

a) (10 points) Consider the first reactor and show that $(k/F_{A0}) = 10^{-3}\ (atm \cdot kg.cat)^{-1}$?
b) (15 points) How much is the conversion exiting the last reactor?
c) (5 points) How much is the pressure at the exit ($P_{exit}$) of the packed bed?
d) (15 points) If the catalyst diameter is decreased 50% ($D_{p1}=2D_{p2}$) and the PBR diameter is increased by 50% ($A_{c1}=1.5A_{c2}$), how $\alpha$, $X_2$ and $P_{exit}$ are going to be? Assuming turbulent flow.



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**Problem 4** (25 points) A liquid phase reaction in a CSTR yields **C** (main product) and **D** (by-product) from an aqueous of **A** and **B.** The reaction is carried out at a constant temperature.

$$\mathbf{A + B \rightarrow C + D}$$

The reaction is an irreversible 4th order (3rd order with respect to reactant **A** and 1st order with respect to reactant **B**). Influent is fed with a volumetric flow rate of 0.2 liter/min. The inlet contains 0.1 mol/liter of **A** and 0.2 mol/liter of **B**.

a) (5 points) Set up the stoichiometric table for this problem.

b) (5 points) Compare the concentration of main product to the concentration of by-product at X=70%. (compare $C_C$ and $C_D$ at X=70%)

c) (10 points) If the reactor volume is 36 liters and gives X=70%, how much is k (reaction rate constant)?

d) (5 points) If we decide to have a system of n reactors in series, how many (n) of 2 gallon-CSTRs do we need to achieve 70% conversion?

**Problem 5** (15 points) Consider a liquid phase reaction operated in a CSTR under a constant temperature. The reaction is found to be followed an elementary rate law.

$$2A \rightarrow B$$

Show that

$$X = \frac{(1 + 2Da) - \sqrt{1 + 4Da}}{2Da}$$

**Keep in mind** that your text book doesn't say everything for this problem!!!

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**Problem 6** (35 points) Gas **A** is fed to a lab-scale PFR at 2 atm and 200 K to produce gas **B** and gas **C**. The operation is controlled at constant pressure and temperature.

$$A \rightarrow B + C$$

The reaction was found to be secondary reaction with $k_{200K}$ = 0.033 (liter/mol) $s^{-1}$

a) (5 points) Do you think the system has $\Delta P$?

b) (15 points) Calculate reactor volume when gas C is produced with a capacity of 100 mol/h and X = 0.8

c) (15 points) If the reactor cross section area is 10 cm, how much is the reactor length when X = 30%? And at X=30%, how much is $C_C$?