

Name.....Student ID.....

PRINCE OF SONGKLA UNIVERSITY  
FACULTY OF ENGINEERING

Final Examination : Semester II

Academic year : 2007

Date : February 19, 2007

Time : 9.00 – 12.00 am

Subject : 231-322 Chemical Engineering Kinetics

Room: R300

and Reactor Design II

ทุกชนิดในการสอบ โทษชั้นต่ำปรับตกในรายวิชานั้น และพักการเรียน  
1 ภาคการศึกษา โทษสูงสุด ให้ออก

1. The exam are not allow to leave an exam room
2. All books, notes, and all computing devices (i.e., calculator and computer) are allowed
3. Do not discuss or ask any person during taking an exam
4. Do all problems, the mark of each problem is listed below

Problem No.	Total Points	Point obtained
1	20	
2	30	
3	15	
4	20	
5	15	
รวม	100	

Please note that the exam must consist of 11 pages (including this page.)

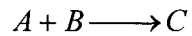
Good luck and do your best on the exam

Assoc. Prof. Dr. Charun Bun rakan

Feb 15, 2007

## 1. (20 points)

The elementary irreversible organic liquid phase reaction



is carried out in an existing adiabatic flow reactor. An equal molar feed in A and B enter at  $27^{\circ}\text{C}$ . The volumetric flow rate and  $C_{A0}$  are  $2 \text{ dm}^3/\text{s}$  and  $0.1 \text{ mol}/\text{dm}^3$ . The additional information are given below:

$$H_A^{\circ}(298) = -20 \text{ kcal/mol}, H_B^{\circ}(298) = -15 \text{ kcal/mol}, H_C^{\circ}(298) = -15 \text{ kcal/mol}$$

$$C_{PA} = C_{PB} = 15 \frac{\text{cal}}{\text{mol K}}, C_{PC} = 30 \frac{\text{cal}}{\text{mol K}}$$

$$k = 0.01 \frac{\text{dm}^3}{\text{mol s}}, \text{ at } 300\text{K}, E = 10,000 \frac{\text{cal}}{\text{mol}}$$

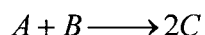
1.1 Calculate the volume of CSTR necessary to achieved 85% conversion of A

1.2 Calculate the volume of PFR necessary to achieved 85% conversion of A

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2 (30 points)

The endothermic liquid-phase elementary reaction



proceeds, substantially, to completion in a single steam-jacketed CSTR. From the following data, calculate the steady-state reactor temperature:

Reactor and reaction:

Reactor volume: 125 gal

Steam jacket area: 10 ft<sup>2</sup>

Steam temperature: 365.9 °F

Overall heat-transfer coefficient of jacket, U: 150 Btu/(hr ft<sup>2</sup> °F)

Agitator shaft horse power: 25 hp (63,525 Btu/hr)

Heat of reaction,  $\Delta H_{rx}^{\circ} = +20,000$  Btu/ lb mol of A (independent of temperature)

Feed condition and feed properties:

Items	Component		
	A	B	C
Feed (lb mol/hr)	10	10.0	0
Feed temperature (°F)	80	80	-
Specific heat Btu/ (lb mol °F)*	51	44	47.5
Molecular weight	128	94	222
Density (lb/ft <sup>3</sup> )	63	67.2	65

\* Independent of temperature

**3 (15 points)**

The first order reaction  $A \longrightarrow B$  is carried out in packed bed reactor packed with porous solid. The reactions were conducted at different particle sizes ( $d_p = 1, 2$  and  $5$  cm). Given that the Thiele modulus of catalyst with  $d_p = 1$  cm is 5

2.1 Estimate the Thiele modulus and the internal effectiveness factor for each particle size.

2.2 Explain what you had learned from the values of the Thiele modulus and the internal effectiveness obtained from 2.1

**Given:** Thiele modulus for first order reaction is define as

$$\phi_1 = R \sqrt{\frac{-r_{As} \rho_c}{D_e C_{As}}}$$

Internal effectiveness factor

$$\eta = \frac{3}{\phi_1^2} (\phi_1 \coth \phi_1 - 1)$$

$$\text{If } \phi_1 > 2 \text{ then } \eta = \frac{3}{\phi_1^2} (\phi_1 - 1)$$

$$\text{If } \phi_1 > 20 \text{ then } \eta = \frac{3}{\phi_1}$$

## 4 (20 points)

The catalytic hydrogenation of methyl linoleate to methyl oleate was carried out in a laboratory-scale slurry reactor in which hydrogen gas was bubbled up through the liquid containing spherical catalyst pellets. The pellet density is  $2 \text{ g cm}^{-3}$ . The following experiments were carried out at  $25^\circ\text{C}$ :

Run	Partial Pressure of $\text{H}_2$ (atm)	Solubility of $\text{H}_2$ ( $\text{mol dm}^{-3}$ )	$\text{H}_2$ Rate of Reaction ( $\text{mol dm}^{-3} \text{min}^{-1}$ )	Catalyst Charge ( $\text{g dm}^{-3}$ )	Catalyst Particle Size ( $\mu\text{m}$ )
1	3	0.007	0.014	3.0	12
2	18	0.042	0.014	0.5	50
3	3	0.007	0.007	1.5	50

4.1 What is the major resistance?

4.2 What should be taken to reduce such resistance?

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5 (15 points)

From problem 4, if the volume of the slurry reactor is  $3 \text{ m}^3$ , the molar feed rate of methyl linoleate is  $0.5 \text{ kmol min}^{-1}$ , the catalyst particle size is  $80 \text{ }\mu\text{m}$ , the partial pressure of  $\text{H}_2$  is  $15 \text{ atm}$  and the reactor is considered to be well mixed, calculate the catalyst charge necessary to achieve 90% conversion of methyl linoleate.