ชื่อ.....รหัส.....

PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Final Examination : Semester II | Academic year : 2006

Date : 23 February 2007 | Time : 13.30 – 16.30 pm

Subject : 231-322 Chemical Engineering Kinetic & Reaction II | Room : R 300

ทุจริตในการสอบ โทษขั้นต่ำปรับตกในรายวิชานั้น และพักการเรียน 1 ภาคการศึกษา โทษสูงสุด ให้ออก

คำสั่ง

1. ห้ามนำข้อสอบบางส่วนหรือทั้งหมดออกจากห้องสอบ
2. อนุญาตให้นำเอกสาร หนังสือ เครื่องคำนวณ ทุกชนิด เข้าห้องสอบได้
3. ห้ามหยิบยืมเอกสารใดๆ และพูดคุยกับนักศึกษาอื่นขณะทำข้อสอบ
4. สามารถใช้ดินสอในการทำข้อสอบได้

ข้อที่	คะแนนเต็ม	คะแนนที่ได้
1	15	
2	20	
3	20	
4	25	
5	20	
รวม	**100**	

ข้อสอบทั้งหมดมี 5 ข้อ 13 หน้า (รวมหน้านี้) กรุณาตรวจสอบความถูกต้องก่อนลงมือทำ

ขอให้นักศึกษาที่ตั้งใจเรียนและมีความมานะขยันทุกคนจงประสบความสำเร็จในการสอบ

รศ.ดร.จรัญ บุญกาญจน์

16 กุมภาพันธ์ 2550

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1. (15 points)

A first-order heterogeneous irreversible reaction

$$A \rightarrow B$$

with a surface reaction rate $-r_A' = k_1 S_a C_{AS}$ $\quad \frac{\text{gmol}}{\text{g cat s}}$

is taking place within a spherical catalyst pellet. The reactant concentration halfway between the external surface and the center of the pellet is equal to 10% of the concentration of the pellet's external surface. The concentration at the external surface is 0.005 g mol/dm^3, the pellet diameter is 2 cm, and the diffusion coefficient is 0.08 cm^2/s.

(a) What is the concentration of reactant at a distance of 0.3 cm from the external pellet surface?

(b) Calculate the Thiele modulus

(c) Calculate the internal effectiveness factor

Additional information:

$k_1 = 2.5 \times 10^{-5}$ m/s

Sa = 150 m^2/g cat

Effective diffusivity = 3.5×10^{-4} m^2/s

Catalyst pellet density = 1200 kg/m^3

$\sinh x = e^x - e^{-x}$

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2. (20 Points)

The reaction

$$2A \rightarrow 2B$$

is first-order in A, that is

$$-r_A' = k_1 S_a C_A, \quad k_1 = 4.5\text{x}10^{-10} \text{ m/s (at 250 °C)}$$

The reaction is carried out in packed bed reactor with 5 cm in inside diameter. The reaction is internal-diffusion-limited. Pure A enters the reactor at a superficial velocity of 3 m/s, a temperature of 250 °C and a pressure of 500 kPa. Calculate the length of bed necessary to achieve 80% conversion.

Additional information:

At 250°C, the fluid properties are

Effective diffusivity (D_e)= $2.5\text{x}10^{-8}$ m^2/s

Gas-phase diffusivity (D_{AB}) = $3.0\text{x}10^{-8}$ m^2/s

Kinematic viscosity = $1.2\text{x}10^{-8}$ m^2/s

The properties of the catalyst and bed are

Catalyst pellet diameter = 0.5 cm

Density of catalyst particle = $2.0\text{x}10^{6}$ g/m^3

Bed porosity = 0.4

Internal surface area = 400 m^2/g

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3. (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 following experiments were carried out at 25 °C.

Run	Partial Pressure of H_2 (atm)	Solubility of H_2 (g mol/dm^3)	H_2 Rate of Reaction (g mol/dm^3 min)	Catalyst Charge (g/dm^3)	Catalyst Particle Size (μm)
1	18	0.042	0.014	0.5	50
2	3	0.007	0.007	1.5	50
3	5	0.012	0.005	2.5	200
4	6	0.014	0.004	5	580

(a) What is the rate limiting step? How could the overall resistance be reduced?

(b) If the 5 m^3 slurry reactor can be modeled as a well-mixed CSTR, calculate the catalyst charge necessary to achieve 80% conversion for a 40 μm particle size. Where the molar feed rate of methyl linoleate to the reactor is 0.5 kmol/min and the solubility of H_2 is 0.02 g mol/dm^3.

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4. (25 points)

The hydrogenation of an unsaturated organic is to be carried out in a trickle bed reactor packed with 0.50-cm-diameter spherical catalyst particles.

$$H_2 + \text{unsaturated} \longrightarrow \text{saturated}$$

The reaction in the pellet is first-order in both hydrogen and the organic. Hydrogen and nitrogen are fed in equimolar portions at a total pressure of 10 atm and a total molar rate of 20 mol/s. The reactor diameter is to be 0.5 m. The superficial liquid mass velocity is 7.0 $kg/m^2 \cdot s$. As a first approximation, assume that the concentration of organic is constant and the pseudo-first-order specific reaction rate is 7×10^{-5} m^3/ kg cat. · s at 400 K. If there is no pressure drop through the bed, calculate the catalyst weight necessary to achieve 30% conversion of the hydrogen.

Additional information:

Liquid viscosity: 0.0018 kg/(m s)

Liquid density = 840 kg/m^3

Effective diffusivity = 3.5×10^{-9} m^2/s

Pellet porosity = 0.4

Pellet density = 1500 kg/m^3

Bed porosity = 0.4

Hydrogen liquid diffusivity in organic = 2.4×10^{-9} m^2/s

Hydrogen solubility = 0.008 kmol/(m^3 atm)

Organic diffusivity in organic product = 1.2×10^{-9} m^2/s

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5. (20 points)

Answer the short questions below

5.1 What is an effective diffusivity? (2 points)

5.2 What is an internal effectiveness factor?(2 points)

5.3 What is an overall effectiveness factor? (2 points)

5.4 What is Weisz-Prater criterion? (2 points)

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(สำรองสำหรับทำโจทย์ข้อที่ 5)

5.5 What is Mears' criterion? (2 points)

5.6 List the factors which affect internal diffusion rate and explain how to increase such rate (2 points)

5.7 List the factors which affect external diffusion and explain how to increase such rate (2 points)

5.8 List the factors which affect the gas absorption resistance in slurry reactor and explain how to reduce such resistance. (2 points)

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5.9 List the factors which affect the specific combined resistance to internal diffusion, reaction, and external external diffusion in slurry reactor and explain how to reduce such resistance. (2 points)

5.10 List the transport step for the slurry reactor and for the trickle bed reactor. Are there different? How? (2 points)