PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Final Examination : Semester II — Academic Year : 2003
Date : 20 February 2004 — Time : 13.30-16.30
Subject : 231-322 Chemical Engineering Kinetics and Reactor Design II — Room : R 300

Student Name: …….. ID No : ……..

Number of questions : 4

Time : 3 hours

Total marks : 100

Books and lecture notes are allowed

Calculators are allowed

Question	Full Marks	Marks Received
1	20	
2	25	
3	25	
4	30	
Total	**100**	

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1)

Adsorption isotherms for hydrogen adsorption on Ni solid was measured in the laboratory. The data in Table below were obtained at 89°C. How well do these data fit the Langmuir adsorption isotherm ? Determine the type of adsorption.

If $$\theta = \frac{\text{concentration of sites with adsorbed molecule on solid catalyst}}{\text{concentration of all monomolecular layer sites on solid catalyst}}$$

$$\theta = \frac{C_{A.S}}{C_t}$$

where A = adsorbed molecule

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Table The amount of hydrogen adsorbed at 89°C on Ni solid sample as a function of the hydrogen pressure

Pressure (torr)	Coverage (monolayer)
6×10^{-7}	0.667
1×10^{-6}	0.781
2×10^{-6}	0.845
3×10^{-6}	0..877
4×10^{-6}	0..89
6.25×10^{-6}	0.91
9×10^{-6}	0..93
1.25×10^{-5}	0.959
1.5×10^{-5}	0.975
2×10^{-5}	0.984

(20 marks)

Answer Q1

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Answer Q1(continued)

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2)

An 8.01-g sample of Glaucosil solid is studied with N_2 adsorption at –195.8°C. The following data are obtained:

Pressure, mm Hg , (p)	6	25	140	230	285	320	430	505
Volume adsorbed, (v) cm^3 (at 0°C and 760 mmHg)	61	127	170	197	215	230	277	335

The vapor pressure (p_o) of N_2 at -195.8 °C is 760 mmHg and density is 0.808 g/cm^3.

a) Plot volume adsorbed vs pressure

b) Plot $\frac{p}{v(p_0 - p)}$ (cc^{-1}) vs $\left(\frac{p}{p_0}\right)$

The BET equation is $\frac{p}{v(p_0 - p)} = \frac{1}{v_m c} + \frac{(c-1)p}{c v_m p_0}$

c) From the plot in (b) determine intercept (I) and slope (s)

Note that: volume of adsorbed gas as monolayer, $v_m = \frac{1}{I + s}$

d) Estimate the surface area in square meters per gram of the sample.

(25 marks)

Answer Q2

Student Name: …….. ID No : ……..

Answer Q2(continued)

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Answer Q2(continued)

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3)

CO reacts with H_2O over Fe_2O_3 catalyst to form H_2 and CO_2. The rate law has been found to agree with the experimental data and is shown below.

$$CO + H_2O \rightarrow H_2 + CO_2$$

$$-r'_{CO} = \frac{k_1 P_{CO} P_{H_2O} - k_2 P_{H_2} P_{CO_2}}{(1 + k_3 P_{CO} + k_4 P_{H_2O} + k_5 P_{CO_2} + k_6 P_{H_2})^2}$$

Base on your experience with other reaction systems, please propose an adsorption-surface reaction-desorption mechanism and specify the rate-limiting step that will explain the experimental rate law for this reaction.

Suggest derivation for the rate law from the proposed mechanism.

(25 marks)

Answer Q3

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Answer Q3(continued)

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4)

a) A well-mixed CSTR with solid catalyst is used to crack crude oil A in the gas phase to gas products. The feed stream contains 80% A and 20% inert I. The reaction is first-order in the crude oil concentration. The catalyst decays with first-order rate in the present activity and first-order in the reactant concentration. The volumetric flow rate to the reactor is 5,000 m^3/h. The reactor contains 50,000 kg of catalyst with bulk density 500 kg/m^3.

$$A\ (g) \rightarrow B\ (g) + C\ (g)$$

$C_{Ao} = 0.8\ mol/dm^3$ $\quad k = \rho_B k' = 45\ h^{-1}$

$C_{To} = 1.0\ mol/dm3$ $\quad k_d = 9\ dm^3/mol.h$

a.1) Explain how to obtain equations for $-da/dt$, dC_A/dt and X(t).

a.2) If it is required to solve these equations for a(t), $C_A(t)$ and X(t) by manual calculation using your hand calculator, explain clearly how to solve them. What are the problems?

a.3) In this problem, explain why conversion decreases with time while C_A increases with time.

a.4) If a = 1.0 at t = 0 h. and C_A = 0.42 and 0.51 mol/dm^3 at 0.1 and 0.3 h respectively, calculate the corresponding X at time 0.1 and 0.3 h

(15 marks)

b) Briefly explain the cause and effects of deactivation of catalyst by sintering.

(5 marks)

c) What is a trickle-bed reactor?

(5 marks)

d) Explain the mechanism of mass transfer at the external surface of solid catalyst for reaction $A \rightarrow B$.

(5 marks)

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Answer Q4

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Answer Q4(continued)

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