

PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Final Examination : Semester II
Date : 20 February 2004
Subject : 231-322 Chemical Engineering
Kinetics and Reactor Design II

Academic Year : 2003
Time : 13.30-16.30
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	

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 N₂ 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 (p₀) of N₂ at -195.8 °C is 760 mmHg and density is 0.808 g/cm³.

a) Plot volume adsorbed vs pressure

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

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

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

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

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

(25 marks)

Answer Q2

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Answer Q2(continued)

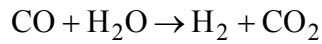
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Answer Q2(continued)

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3)

CO reacts with H₂O over Fe₂O₃ catalyst to form H₂ and CO₂. The rate law has been found to agree with the experimental data and is shown below.



$$-r'_{\text{CO}} = \frac{k_1 P_{\text{CO}} P_{\text{H}_2\text{O}} - k_2 P_{\text{H}_2} P_{\text{CO}_2}}{(1 + k_3 P_{\text{CO}} + k_4 P_{\text{H}_2\text{O}} + k_5 P_{\text{CO}_2} + k_6 P_{\text{H}_2})^2}$$

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

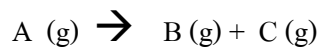
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Answer Q3(continued)

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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 m³/h. The reactor contains 50,000 kg of catalyst with bulk density 500 kg/m³.



$$C_{A0} = 0.8 \text{ mol/dm}^3 \quad k = \rho_B k' = 45 \text{ h}^{-1}$$

$$C_{T0} = 1.0 \text{ mol/dm}^3 \quad k_d = 9 \text{ dm}^3/\text{mol.h}$$

- 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



(5 marks)

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Answer Q4

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Answer Q4(continued)

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