CATALYSIS AND CATALYTIC REACTOR DESIGN (SEMESTER - 6)

CS/B.TECH (CHE-N)/SEM-6/CHE-605B/09

1. .....
Signature of Invigilator

2. .....
Signature of the Officer-in-Charge

Reg. No. | | | | | | | | | | | | | | |

Roll No. of the Candidate | | | | | | | | | | | | | | |

CS/B.TECH (CHE-N)/SEM-6/CHE-605B/09

ENGINEERING & MANAGEMENT EXAMINATIONS, JUNE – 2009

CATALYSIS AND CATALYTIC REACTOR DESIGN (SEMESTER - 6)

Time : 3 Hours] [Full Marks : 70

INSTRUCTIONS TO THE CANDIDATES :

1. This Booklet is a Question-cum-Answer Booklet. The Booklet consists of **32 pages**. The questions of this concerned subject commence from Page No. 3.
2. a) In **Group – A**, Questions are of Multiple Choice type. You have to write the correct choice in the box provided **against each question**.
   b) For **Groups – B** & **C** you have to answer the questions in the space provided marked 'Answer Sheet'. Questions of **Group – B** are Short answer type. Questions of **Group – C** are Long answer type. Write on both sides of the paper.
3. **Fill in your Roll No. in the box** provided as in your Admit Card before answering the questions.
4. Read the instructions given inside carefully before answering.
5. You should not forget to write the corresponding question numbers while answering.
6. Do not write your name or put any special mark in the booklet that may disclose your identity, which will render you liable to disqualification. Any candidate found copying will be subject to Disciplinary Action under the relevant rules.
7. **Use of Mobile Phone and Programmable Calculator is totally prohibited in the examination hall.**
8. You should return the booklet to the invigilator at the end of the examination and should not take any page of this booklet with you outside the examination hall, **which will lead to disqualification**.
9. Rough work, if necessary is to be done in this booklet only and cross it through.

No additional sheets are to be used and no loose paper will be provided

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FOR OFFICE USE / EVALUATION ONLY

Marks Obtained

	Group – A										Group – B			Group – C				
Question Number																	***Total Marks***	***Examiner's Signature***
Marks Obtained																		

.....
Head-Examiner/Co-Ordinator/Scrutineer

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GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : 10 × 1 = 10

i) A catalyst

a) initiates a reaction

b) lowers the activation energy of reacting molecules

c) is capable of reacting with any one of the reactants

d) cannot be recovered chemically unchanged at the end of a chemical reaction. ☐

ii) What is the Thiele modulus of the solid catalysed first order reaction $A \xrightarrow{K} B$, if the pore diffusion offers negligible resistance to reaction ?

a) < 5 b) < 0·5

c) > 1 d) 5. ☐

iii) The vessel dispersion number ($D/\mu L$) for plug flow is

a) 0 b) 500

c) 750 d) infinite. ☐

iv) The vessel dispersion numbeer ($D/\mu L$) for perfect mixed flow is

a) 0 b) > 150

c) < 2100 d) infinite. ☐

v) Promoter is added to catalyst to improve its

a) porosity b) sensitivity

c) surface area d) none of these. ☐

vi) For a solid catalysed reaction, the effectiveness of solid catalyst depends upon ..... adsorption.

a) physical b) chemical

c) both (a) and (b) d) neither (a) nor (b). ☐

vii) Carrier in a catalyst increases its

a) surface area b) activity

c) performance d) none of these. ☐

viii) B.E.T. method of finding out surface area of a catalyst, uses the extension of ..... isotherm.

a) Langmuir b) Freundlich

c) Tempkin d) none of these. ☐

ix) ..... gas is normally employed in B.E.T. method of finding out surface area of a catalyst.

a) N_2 b) H_2

c) CO_2 d) He. ☐

x) Effectiveness factor for a first order reaction is given by

a) tan hT/T b) tan T/T

c) tan hT / tan T d) none of these

where, T = Thiele modulus = $L\sqrt{\frac{K}{D}}$. ☐

xi) ..... is added as a promoter to iron catalyst in ammonia synthesis reaction.

a) Silica b) Alumina

c) Nickel d) None of these. [ ]

xii) Fractional conversion ..... with increase in pressure for ammonia synthesis reaction.

a) increases b) decreases

c) remains unchanged d) unpredictable from the data. [ ]

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following questions. 3 × 5 = 15

2. Explain different steps in a heterogeneous catalytic reaction. 5

3. The catalytic reaction $A \rightarrow 4R$ is taking place. The rate of the reaction, $-r'_A = 96 \frac{\text{lit}}{\text{hr . kgcat.}} C_A \left(\frac{\text{mol}}{\text{lit}} \right)$. Determine the amount of catalyst needed in a packed bed reactor (assume there is no dispersion) for 35% conversion of A to R for a feed of 2000 mol/hr of pure A at 3·2 atm and 117°C. 5

4. a) A reaction is taking place between an adsorbed molecule of A and gaseous molecule of B at the surface. The overall reaction is of the type

$$A + B \rightleftharpoons C$$

Derive the expression of the rate of surface reaction. Also determine the expression of equilibrium constant. 5

OR

b) Define micropore, mesopore and macropore. 1 + 2 + 2

5. Derive the Langmuir adsorption isothern in terms of concentration of solute. 5

6. Describe the different methods of catalyst preparation. 5

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following questions. 3 × 15 = 45

7. 8·01 gm sample of Glaucosil is studied with adsorption of N_2 at – 195·8°C. The following data are obtained :

Pressure mm Hg	6	25	140	230	285	320	430	505
Volume adsorbed, cm^3 (at 0°C and 1 atm)	61	127	170	197	215	230	277	335

The vapour pressure of N_2 at – 195·8°C is 1 atm. Calculate the surface area in cm^2 /gm of the sample. 15

8. a) What is poisoning of a catalyst ? 2

b) The effect of bypassing in a bubbling fluidized bed is determined by the fraction ($1 - \varepsilon_d$) of the reactor volume that consists of bubbles and by the relative values of the reaction rate and mass transfer rate. The quantities k_m , ε_d , u_b and a_v all depend upon the bubble diameter. In a particular case suppose that these parameters have the following values, for a first order operating isothermally in the bubbling regime :

The denity of catalyst particles in the dense phase, $\rho_d = 0{\cdot}01$ g/cm^3

($k_m a_v$) = 0·60 s^{-1}

where, k_m = mass transfer coefficient between bubble and dense phases

a_v = mass transfer area between bubble and dense phases per unit volume of reactor

Reaction rate constant, k = 50 cm^3 /(gm cat.) (s)

Velocity of feed, u_b = 10 cm/s

Reactor height, $z = L$ = 40 cm

ε_d = 0·80 (that is, 20% of the reactor volume is occupied by gas bubbles and 80% by the dense phase)

i) Calculate the conversion in the effluent. 8

ii) For comparison, calculate the conversion for plug-flow and stirred tank reactors with the same apparent bubble residence time. 5

9. a) At 700°C the rate of decomposition, $A \rightarrow 3R$, on a specific catalyst of given size is found to be

$$-r'_A = -\frac{1}{W}\frac{dN_A}{dt} = 10 \frac{\text{lit}}{\text{hr.gmcat.}} \; C_A \left(\frac{\text{mol}}{\text{lit}}\right)$$

A pilot plant is to be built. This is to be a tubular packed bed 2 cm ID using 25% of these active catalyst pellets evenly mixed with 75% inert pellets to ensure isothermal operations. For 400 mol/hr feed consisting of 50% A-50% inert gas at 8 atm. At 700°C what must be the length of reactor so that

$p_{A\,out} / p_{A\,in} = 0{\cdot}111.$

Data : Catalyst and inert pellets are porous, of diameter, $d_p = 3$ mm

Particle density, $\rho_s = 2$ gm/cm^3

Bulk voidage of packed bed = 50%. 12

b) Write the assumptions involved in deriving Langmuir isotherm equation. 3

10. The catalytic reaction $A \rightarrow 4R$ is studied in a plug flow reactor using various amounts of catalyst and 20 lit/hr of pure A feed at 3·2 atm and 117°C. The concentration of A in the effluent stream is recorded for the various runs as follows :

Runs	1	2	3	4	5
Catalyst used, kg	0·020	0·040	0·080	0·120	0·160
$C_{A\,out}$, mol/lit	0·074	0·060	0·044	0·035	0·029

a) Find the rate equation for this relation, using the integral method of analysis. 8

b) Repeat part (a), using the differential method of analysis. 7

11. a) Derive the material and energy balance equations describing diffusion with first order reaction in a non-isothermal packed bed reactor. At first derive the equations for a single catalyst pellet and then derive for the entire bed of the reactor. 12

b) Distinguish between promoters and inhibitors. 3

END