Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(CHE)/SEM-6/CHE-605 B/2012

2012
CATALYSIS & CATALYTIC REACTOR DESIGN

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.
Log-log graph sheet & ordinary graph sheet, if required, will be provided by the institution.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

i) A reaction is of zero order when the rate of reaction is

a) independent of concentration of materials

b) independent of total pressure

c) dependent on partial pressure of reactants

d) dependent on total pressure.

ii) For irreversible reaction in series $A \xrightarrow{\Re_1} R \xrightarrow{\Re_2} S$ where $\Re_1$ and $\Re_2$ are first order reaction rates constants the time at which the maximum concentration of R (t_{max}) occurs is

a) $\dfrac{\ln(\Re_2 - \Re_1)}{\Re_2/\Re_1}$ b) $\dfrac{\ln(\Re_2/\Re_1)}{\Re_2 - \Re_1}$

c) $\left(\dfrac{\Re_1}{\Re_2}\right)^{\Re_2/(\Re_2-\Re_1)}$ d) None of these.

iii) Thiele modulus for first order reaction is given by

a) $\sqrt{\Re/D}$ b) $L\sqrt{\Re/D}$

c) $\sqrt{\dfrac{\Re L}{D}}$ d) $\sqrt{\dfrac{\Re}{LD}}$.

Where $\Re$ is reaction rate constant, D is diffusion coefficient and L is the length of the pore.

iv) A catalyst is made into pellets. The mass of the pellet is 3.0 gm and the volume is 3.5 cm^3. The macropore volume of the pellet is 0.65 cm^3. Then the macropore volume per gm is

a) 3.0/0.65 b) 3.5/3.0

c) 0.65/3.0 d) 0.65/3.5.

v) Effectiveness Factor for a porous catalyst is given by

a) $\dfrac{\tanh mL}{mL}$ b) $\dfrac{mL}{\tanh mL}$

c) $\dfrac{\tanh mL}{1+mL}$ d) $\dfrac{1+mL}{\tanh mL}$.

vi) In a porous catalyst, for surface kinetics, the rate of reaction of *A* mav depend on

a) Adsorption of *A* on the the surface, reaction on the surface or desorption of product back into gas stream

b) Adsorption of *A* on the the surface, and desorption only

c) Adsorption of *A* on to the surface and chemical reaction only

d) None of these.

vii) For small value of Thiele modulus (less than 0.4), the effectiveness factor is approximately equal to

a) 10 b) 1.0

c) 0.1 d) 0.01.

viii) Carrier in a catalyst increases its

a) surface area b) activity

c) performance d) none of these.

ix) The rate limiting step is

a) fastest step

b) slowest step

c) $\frac{1}{2}$ of the fastest step

d) average of fastest and slowest steps.

x) Carbon particles accumulated on the catalyst used in the gas oil cracking lies in the category of

a) deposited poison b) chemisorbed poison

c) selectivity poison d) stability poison.

xi) A bidisperse catalyst contains

a) mesopores only b) micropores only

c) macropores only d) both (b) and (c).

xii) The main advantage of nano-sized catalyst is

a) high surface area

b) low cost

c) easy preparation process

d) none of these.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Write short notes on the nitrogen desorption method for pore volume distribution measurement

3. Describe the activity of promoters and inhibitors in a reaction with examples.

4. Describe different catalyst poisoning with examples.

5. Derive the Langmuir-Hinshelwood kinetics for a catalytic reaction.

6. Assumptions involved in deriving Langmuir isotherm equation.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. 9.12 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 and the density of N_2 at –195.8°C is 0.808 gm/cm^3. Calculate the surface area in cm^2 of the sample.

8. Butyl acetate is produced from Butanol and acetic acid in a batch reactor at 100°C with small amount of sulphuric acid as homogeneous catalyst. Original feed contains 5.0 moles

Butanol/mole of acetic acid and the catalyst concentration is 0.03% by weight. The rate expression is given by $r_A = - \Re C_A^2$ When C_A is the concentration of acetic acid and $\Re$ is 17.5 $cm^3/(g.mol)$ (min). The densities of mixtures of reactant and products can be assumed to be constant at 0.78 gm/cm^3. Calculate the time required to obtain a conversion of 60%. Also determine the size of the reactor in order to produce Butyl acetate at an average rate of 50 kg/hour. Only one reactor will be used and this unit will be shut down 30 min between batches. Given molecular weight of butanol = 74, acetic acid = 60 and ester = 116.

9. Oxidation of NO is catalyzed by the active carbon according to the following rate of equation at 30°C.

Rate = $r = \dfrac{(p_{NO})^2 \left(p_{O_2}\right)}{a + b\left(p_{NO}\right)^2 + cp_{NO_2}}$ g.moles NO converted/ (gm catalyst) (hr)

p is the partial pressure, atm.

$a = 1.619 \times 10^{-4}$

$b = 4.842$

$c = 1.52 \times 10^{-3}$

Find the volume of the flow reaction for converting 50 tons/day of NO_2 when using air – NO mixture containing 1.5 mole % NO and the conversion is 90%. Bulk sp. gravity of the catalyst is 0.48 and the total pressure is 3 atm.

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

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

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 insure 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 $p_{Aout}/p_{Ain} = 0.111$

Data :

Catalyst and inert pellets are porous, of diameter, d_p = 3mm;

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

Bulk voidage of packed bed = 50%.

b) "A 3rd order catalytic reaction behaves like a reaction of 2nd order in the region of strong pore resistance." Justify the statement. 12 + 3

11. The catalytic reaction $A \rightarrow 4R$ is studied in a plug flow reactor using various amount 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_{Aout}, 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.

b) Repeat part (a), using the differential method of analysis. 8 + 7