



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.*

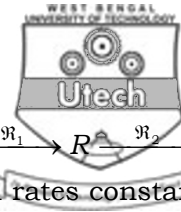
**GROUP – A**

**( 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  $A \xrightarrow{\mathfrak{R}_1} R \xrightarrow{\mathfrak{R}_2} S$  where  $\mathfrak{R}_1$  and  $\mathfrak{R}_2$  are first order reaction rates constants the time at which the maximum concentration of  $R$  ( $t_{max}$ ) occurs is

- a)  $\frac{\ln(\mathfrak{R}_2 - \mathfrak{R}_1)}{\mathfrak{R}_2 / \mathfrak{R}_1}$       b)  $\frac{\ln(\mathfrak{R}_2 / \mathfrak{R}_1)}{\mathfrak{R}_2 - \mathfrak{R}_1}$   
 c)  $\left(\frac{\mathfrak{R}_1}{\mathfrak{R}_2}\right)^{\mathfrak{R}_2 / (\mathfrak{R}_2 - \mathfrak{R}_1)}$       d) None of these.

- iii) Thiele modulus for first order reaction is given by

- a)  $\sqrt{\mathfrak{R}/D}$       b)  $L\sqrt{\mathfrak{R}/D}$   
 c)  $\sqrt{\frac{\mathfrak{R}L}{D}}$       d)  $\sqrt{\frac{\mathfrak{R}}{LD}}$ .

Where  $\mathfrak{R}$  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<sup>3</sup>. The macropore volume of the pellet is 0.65 cm<sup>3</sup>. Then the macropore volume per gm is

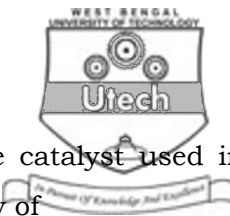
- a) 3.0/0.65      b) 3.5/3.0  
 c) 0.65/3.0      d) 0.65/3.5.

- v) Effectiveness Factor for a porous catalyst is given by

- a)  $\frac{\tanh mL}{mL}$       b)  $\frac{mL}{\tanh mL}$   
 c)  $\frac{\tanh mL}{1 + mL}$       d)  $\frac{1 + mL}{\tanh mL}$ .



- vi) In a porous catalyst, for surface kinetics, the rate of reaction of A may depend on
- Adsorption of A on the the surface, reaction on the surface or desorption of product back into gas stream
  - Adsorption of A on the the surface, and desorption only
  - Adsorption of A on to the surface and chemical reaction only
  - None of these.
- vii) For small value of Thiele modulus (less than 0.4), the effectiveness factor is approximately equal to
- 10
  - 1.0
  - 0.1
  - 0.01.
- viii) Carrier in a catalyst increases its
- surface area
  - activity
  - performance
  - none of these.
- ix) The rate limiting step is
- fastest step
  - slowest step
  - $\frac{1}{2}$  of the fastest step
  - 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 )

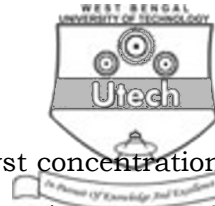
Answer any *three* of the following.  $3 \times 15 = 45$

7. 9.12 gm sample of Glaucosil is studied with adsorption of  $N_2$  at  $-195.8^\circ\text{C}$ . The following data are obtained :

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

The vapour pressure of  $N_2$  at  $-195.8^\circ\text{C}$  is 1 atm and the density of  $N_2$  at  $-195.8^\circ\text{C}$  is  $0.808 \text{ gm/cm}^3$ . Calculate the surface area in  $\text{cm}^2$  of the sample.

8. Butyl acetate is produced from Butanol and acetic acid in a batch reactor at  $100^\circ\text{C}$  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  $r_A = -\mathfrak{R} C_A^2$

When  $C_A$  is the concentration of acetic acid and  $\mathfrak{R}$  is  $17.5 \text{ cm}^3/(\text{g.mol}) (\text{min})$ . The densities of mixtures of reactant and products can be assumed to be constant at  $0.78 \text{ gm/cm}^3$ . 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  $30^\circ\text{C}$ .

$$\text{Rate} = r = \frac{(p_{\text{NO}})^2 (p_{\text{O}_2})}{a + b (p_{\text{NO}})^2 + c p_{\text{NO}_2}} \text{ g.moles NO converted / (gm catalyst) (hr)}$$

$p$  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  $\text{NO}_2$  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  $700^\circ\text{C}$  the rate of decomposition,  $A \rightarrow 3R$ , on a specific catalyst of given size is found to be

$$-r_A^t = -\frac{1}{W} \frac{dN_A}{dt} = 10 \frac{\text{lit}}{\text{hr. gmcat.}} C_A \left( \frac{\text{mol}}{\text{lit}} \right)$$

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 insure isothermal operations. For 400 mol/hr feed consisting of 50% A-50% inert gas at 8 atm. At  $700^\circ\text{C}$  what must be the length of reactor so that  $p_{Aout}/p_{Ain} = 0.111$

Data :

Catalyst and inert pellets are porous, of diameter,  $d_p = 3\text{mm}$ ;

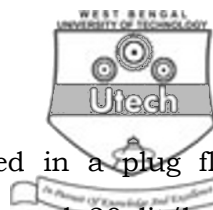
Particle density,  $\rho_s = 2/\text{cm}^3$

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

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