# CATALYSIS AND CATALYTIC REACTOR DESIGN
# (CHEN 4241)

**Time Allotted : 3 hrs** **Full Marks : 70**

***Figures out of the right margin indicate full marks.***

***Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.***

***Candidates are required to give answer in their own words as far as practicable.***

## Group – A
## (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Vapour phase oxidation of naphthalene is carried out in presence of $V_2O_5$ catalyst. The reaction
(a) is considered as homogeneous
(b) is considered as heterogeneous
(c) may be either homogeneous or heterogeneous
(d) none of the above

(ii) Temperature dependency of rate constant (k) is given by, $k = k_0T^m\exp(-E/RT)$. The value of m for Arrhenius law is
(a) 0 (b) 1 (c) 0.5 (d) none of the above

(iii) Under strong pore diffusion regime, the relation between true activation energy and observed activation energy is given by
(a) $E_{true} = E_{obs}/2$ (b) $E_{true} = 2\ E_{obs}$ (c) $E_{true} = E_{obs}$ (d) $E_{true} = (E_{obs})^{0.5}$

(iv) For reaction under pore diffusion regime, the reaction rate
(a) varies directly with catalyst particle size
(b) varies inversely with catalyst particle size
(c) is independent of catalyst particle size
(d) none of the above

(v) The dimensions of $k_3$ present in Briggs Halden equation are
(a) $(time)^{-1}$ (b) volume (c) mol/volume (d) volume/mol

(vi) The plot of rate versus substrate concentration of an enzymatic reaction gives a section of rectangular hyperbola. The system represents a
(a) shifting order reaction (b) first order reaction
(c) zero order reaction (d) none of the above

(vii) A promoter is a substance which
(a) improves activity of the catalyst only
(b) improves selectivity of the catalyst only
(c) stabilizes the catalytic agent only
(d) improves activity or selectivity or stabilizes the catalytic agent

(viii) The yield coefficient of cell growth ($Y_{A/C}$) is
(a) constant during exponential phase of growth
(b) constant during stationary phase of growth
(c) the slope of $C_C$ versus $C_A$ line
(d) the slope of $C_A$ versus $C_A$ line

(ix) Substrate concentration ($C_A$) in terms of cell concentration($C_C$) is given by
(a) $C_{A0} - C_A = Y_{A/C} ( C_C - C_{C0})$ (b) $C_{A0} - C_A = Y_{C/A} ( C_C - C_{C0})$
(c) $C_{A0} - C_A = ( C_C - C_{C0})$ (d) none of the above

(x) At high $C_A$, the Monod equation gives performance equation of
(a) exponential growth curve (b) S- shaped growth curve
(c) linear growth curve (d) none of the above

## Group – B

2. (a) Show that for a first order solid catalyzed gas reaction under strong pore diffusion resistance, the effectiveness factor is given by:

$$\eta = \frac{\tanh\phi}{\phi} \text{ where } \phi = Thiele \text{ modulus}$$

(b) The following kinetic data on the reaction A → R are obtained in an experimental packed bed reactor using various amounts of catalyst and a fixed feed rate $F_{A0}$ = 10 kmol/hr.

| W, kg cat | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $X_A$ | 0.12 | 0.20 | 0.27 | 0.33 | 0.37 | 0.41 | 0.44 |

(i) Find the reaction rate at 40% conversion.
(ii) In designing a large packed bed reactor with feed rate $F_{A0}$ = 400 kmol/hr how much catalyst would be needed for 40% conversion.
(iii) How much catalyst would be needed in part (b) if the reactor employed a very large recycle of product stream.

**6 + 6 = 12**

3. (a) What is an integral reactor? How it is used to determine the rate equation of a solid catalyzed gas reaction.

(b) The solid catalyzed decomposition of gaseous A proceeds as follows:

$$A \rightarrow R \quad (-r_A) = k\, C_A^2$$

A tubular pilot plant reactor packed with 2 liters of catalyst is fed 2 $m^3$ / hr of pure A at $300^0$C and 20 atm. Conversion of reactant is 65%.

In a larger plant it is desired to treat 100 $m^3$/hrof feed gas at 40 atm and $300^0$C containing 60% A and 40% inert to obtain 85% conversion of A. find the internal volume of the reactor required.

**6 + 6 = 12**

## Group – C

4. (a) (i) Discuss in details the working principles of trickle Bed reactor.
(ii) Classify different types of bioreactor

(b) Derive Michaelis- Menten equation from the first principle and show that it represents the equation of a section of rectangular hyperbola.

**(4 + 2) + 6 = 12**

5. The rate of reaction of an enzyme catalyzed reaction was determined in the presence of an inhibitor B. The data in the presence and absence of the inhibitor are shown in the table below. Determine the nature of inhibition and the rate expression of the reaction.

| Substrate concentration (mmol/liter) | 0.2 | 0.33 | 0.5 | 1.0 | 2.5 | 4.0 | 5.0 |
|---|---|---|---|---|---|---|---|
| Rate with no inhibitor, (mmol/liter.min) | 8.34 | 12.48 | 16.67 | 25.0 | 36.2 | 40.0 | 42.6 |
| Rate with $C_{B0}$ = 5 μmol/liter (mmol/liter.min) | 3.15 | 5.06 | 7.12 | 13.30 | 26.2 | 28.9 | 31.8 |

**12**

## Group – D

6. An 8.01 gm sample of glucosil is studied with $N_2$ adsorption at – $195.8^0$C. Thefollowing data are obtained:

| Pressuremm Hg | 6 | 25 | 140 | 230 | 285 | 320 | 430 | 505 |
|---|---|---|---|---|---|---|---|---|
| Volume adsorbedat $0^0$C, 1 atm, $cm^3$ | 61 | 127 | 170 | 197 | 215 | 230 | 277 | 339 |

The vapour pressure of $N_2$ at =$195.8^0$C is 1 atm. Estimate the surface area in $m^2$ / gm of the sample. For Nitrogen gas,use the following data:
$N_0 = 6.032 \times 10^{23}$, M = 28, V = 22400 $cm^3$ / mol and density = 0.808 gm / $cm^3$.

**12**

7. (a) Discuss in details the general methods of preparation of catalyst.

(b) Write a short note on catalyst deactivation.

**6 + 6 = 12**

# Group – E

8. (a) A fermentation industry wishes to produce a valuable biochemical by maintaining maximum rate of cell growth condition as far as possible. Starting with 15.5 mg / $dm^3$ of cells and 150 mg / $dm^3$ of substrate, the fermentation was carried out. The yield of cell was found to be 0.65 mg cell / mg substrate. The cell growth rate was reported to be $R_C = 1.2\ C_A C_C / (C_A + 2)$ mg cells formed / hr. $dm^3$, where $C_A$ and $C_C$ are substrate and cell concentrations respectively. Find the maximum rate of cell growth that can be achieved at this condition. Derive the equation you have used.

   (b) Derive the performance equation (in terms of substrate concentration) of chemoststs used for fermentation reaction following Monod equation.

**8 + 4 = 12**

9. (a) A strain of mold was grown in a batch culture on glucose and the following data were obtained

| Time (h) | 0 | 9 | 16 | 23 | 30 | 34 | 36 | 40 |
|---|---|---|---|---|---|---|---|---|
| Cell concentration (g/l) | 1.25 | 2.45 | 5.1 | 10.5 | 22 | 33 | 37.5 | 41 |
| Glucose concentration (g/l) | 100 | 97 | 90.4 | 76.9 | 48.1 | 20.6 | 9.38 | 0.63 |

Show that the system follows Monods substrate uninhibited equation

   (b) Assume the experimental measurements for a certain organism have shown that cells can convert two-thirds (wt/wt) of the substrate carbon to biomass. Calculate the stoichiometric coefficients for the following biological reactions.

$$C_{16}H_{34} + a\ O_2 + b\ NH_3 \rightarrow c\ (C_{4.4}H_{7.3}N_{0.86}O_{1.2}) + d\ H_2O + e\ CO_2$$

**6 + 6 = 12**

| Department & Section | Submission Link |
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| CHE | https://classroom.google.com/c/Mjg3NDMzNTk5Nzk0/a/MzU5MzIxMzgwNzc4/details |