CHEMICAL REACTION ENGINEERING - II
(CHEN 3111)

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) Catalyst is a substance which enhances the chemical reaction rate
(a) by providing an alternate reaction path
(b) by increasing collisions between molecules
(c) by increasing the activation energy
(d) none of the above.

(ii) In homogeneous catalyzed system, the observed rate is the
(a) rate due to catalyzed reaction only
(b) rate due to uncatalyzed reaction only
(c) rate due to both uncatalyzed and catalyzed reactions
(d) none of the above.

(iii) Promoter is added to the catalyst to improve its
(a) Porosity (b) Sensitivity (c) Surface area (d) None of these.

(iv) Effectiveness factor of a catalyst pellet is a measure of the _____ resistance.
(a) bulk diffusion (b) pore diffusion
(c) surface phenomenon (d) none of the above

(v) The characteristic length (L) in Thiele Modulus for cylinder of radius R is given by
(a) L = 2R (b) L = R / 3 (c) L = R / 2 (d) None of the above.

(vi) A catalyst inhibitor
(a) lessens its selectivity
(b) may be useful for suppressing undesirable side reactions
(c) is added in small quantity during the catalyst manufacture itself
(d) all of the above.

(vii) Rate determining step in a reaction consisting of a number of steps in series is the/ may be _____ step.
(a) slowest (b) fastest
(c) any intermediate (d) none of the above.

(viii) For a differential flow reactor, the
(a) rate is to be constant at all points within the reactor
(b) rate may vary at all points within the reactor
(c) system is in equilibrium
(d) none of the above.

(ix) Choose the fluid particle reaction where the particle does not change in size:
(a) $C(s) + 2S(g) \rightarrow CS_2(g)$
(b) $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$
(c) $4FeS_2(s) + 11O_2(g) \rightarrow 8SO_2(g) + 2Fe_2O_3(s)$
(d) $NaNH_2(l) + C(s) \rightarrow NaCN(l) + H_2(g)$

(x) Tank-in-series model belongs to
(a) zero adjustable parameter model
(b) one adjustable parameter model
(c) two adjustable parameter model
(d) none of the above.

Group- B

2. (a) Define:
i. Catalysis
ii. Catalyst
iii. Promoter
iv. Inhibitor. [(CO1)(Analyze/IOCQ)]

(b) (i) Discuss in details the general methods of catalyst preparation.
(ii) What are the different reasons for catalyst deactivation? Discuss them in details.
[(CO1)(Analyze/IOCQ)]
4 + (4 + 4) = 12

3. (a) How the surface area of catalyst is estimated by BET method?
[(CO1)(Remember/LOCQ)]

(b) Low temperature (- 195.8^{0}C) nitrogen-adsorption data were obtained for an Fe-Al_2O_3 ammonia catalyst. The results for a 50.4 g sample were:

Pressure, mm Hg	8	30	50	102	113	148	233	258	330	442	480	507	550
Volume adsorbed, cm^3 (at 0^{0}C and 1 atm)	103	116	130	148	159	163	188	198	221	270	294	316	365

Estimate the specific surface area for this catalyst. [(CO2)(Evaluate/HOCQ)]
5 + 7 = 12

Group - C

4. (a) (i) Prove that for a first order gas reaction A→R, carried out under pore diffusion limitation in presence of a single porous catalyst pellet cylindrical in shape:
Effectiveness factor $(\eta) = \frac{tanh\,\text{mL}}{\text{ml}}$; where, mL is the Thiele modulus. Also show that under strong pore diffusion regime an nth order reaction will behave as $\frac{n+1}{2}th$ order reaction and activation energy (E_{obs}) = $\frac{E_{True}}{2}$. [(CO3)(Evaluate/HOCQ)]

(b) The catalytic reaction A → 4R is studied in a plug flow reactor using various amounts of catalyst and 20 liters/hr of pure A feed at 3.2 atm and 117°C. The concentrations of A in the effluent stream are recorded for the various runs as follows.

Run	1	2	3	4
Catalyst used,kg	0.020	0.040	0.080	0.160
C_{Aout}, mol/liter	0.074	0.060	0.044	0.029

Find the rate equation for this reaction, using the integral method of analysis.

[(CO3)(Evaluate/HOCQ)]

(3 + 4) + 5 = 12

5. The solid catalyzed decomposition of gaseous A proceeds as follows:

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

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

In a larger plant it is desired to treat 100 m^3/hr of feed gas at 40 atm and 300^0C containing 60% A and 40% inert to obtain 85% conversion of A. Find the internal volume of the reactor required. [(CO3)(Evaluate/HOCQ)]

12

Group - D

6. (a) Derive the equation relating time versus conversion in case of non-catalytic gas-solid reaction (shrinking-core model) for spherical particle of unchanging size where chemical reaction controls. [(CO4)(Analyze/IOCQ)]

(b) A batch of solids of uniform size is treated by gas in a uniform environment. Solid is converted to give a non-flaking product according to the shrinking-core model. Conversion is about $\frac{7}{8}$ for a reaction time of 1 hr., conversion is complete in two hrs. What mechanism is rate controlling? [(CO4)(Evaluate/HOCQ)]

6 + 6 = 12

7. (a) (i) Give one example for each of fluid-particle reaction (SCM model) of spherical particle for unchanging size and changing size.

(ii) Discuss with examples, the different flow patterns in fluid-particle reactor. [(CO4)(Understand/LOCQ)]

(b) A solid feed consisting of the following sized particles:
20 wt% of 1 mm particles and smaller
45 wt% of 2 mm particles and smaller
Rest 3 mm particles and smaller
The feed passes through a rotating tubular reactor somewhat like a cement kiln where, it reacts with gas to give a hard non-friable solid product (SCM/reaction control, $\tau = 3h$ for 3 mm particles.
Find the mean conversion of the solids for a residence time of 45 minutes.

[(CO4)(Evaluate/HOCQ)]

(2 + 2) + 8 = 12

Group - E

8. (a) (i) Give an example of a fluid-fluid reaction.
(ii) Discuss the factors required to be considered during design of a reactor for a 'Gas/Liquid reaction. [(CO4)(Remember/LOCQ)]

(b) Gaseous A absorbs and reacts with B in liquid according to
$A\ (g \rightarrow l) + B\ (l) \rightarrow R\ (l)$
in a packed bed under conditions where,
$k_{Ag}a$= 0.1 mol/hr. m^3 of reactor. Pa, $k_{Al}a$= 100 m^3 of liquid/ m^3 of reactor. hr.
a=100 m^2/ m^3 of reactor, $D_{Al}=D_{Bl}=10^{-6}$ m^2/hr.
f_l=0.1 m^3 of liquid/ m^3 of reactor, k= 10 m^3 of liquid/mol.hr.
Henry's Law constant, H_A= 10^3 Pa. m^3 liquid/mol.
Calculate the rate of reaction in mol/hr. m^3 of reactor at a point in the reactor, where p_A= 105 Pa and C_B = 190 mol/ m^3 liquid. [(CO5)(Evaluate/HOCQ)]

(1 + 4) + 7 = 12

9. (a) A real CSTR has been modelled using bypassing and dead space. For the first order reaction, $A \rightarrow B$, derive the expression of conversion in terms of model parameters. [(CO5)(Analyze/IOCQ)]

(b) A positive step tracer input has been applied to determine the above model parameters. Obtain the method to determine model parameters. [(CO5)(Analyze/IOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	14.58	31.25	54.17

Course Outcome (CO):

After the completion of the course students will be able to

1. To participate in catalyst development programme.
2. To characterize newly developed catalyst.
3. To design catalytic reactors.
4. To design non catalytic reactors involving solid fluid reaction.
5. To design reactors involving mass transfer with chemical reactions.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question