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) Roasting of zinc sulphide to yield hard zinc oxide is an example of
(a) catalytic heterogeneous reaction
(b) catalytic homogeneous reaction
(c) non-catalytic heterogeneous reaction
(d) non-catalytic homogeneous reaction.

(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) Roasting of zinc sulphide to yield hard zinc oxide is an example of
(a) catalytic heterogeneous reaction (b) catalytic homogeneous reaction
(c) non-catalytic heterogeneous reaction (d) non-catalytic homogeneous reaction.

(vii) Choose the fluid particle reaction where the particle does not change in size:
(a) $2C(s) + O_2(g) \rightarrow 2CO(g)$
(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) $NaNH_2(l) + C(s) \rightarrow NaCN(l) + H_2(g)$.

(viii) $\frac{t}{\tau} = X_B$, where τ is time for complete conversion. The above time (t) versus fractional conversion (X_B) equation holds good for shrinking core model of unchanging size when
(a) chemical reaction controls
(b) when diffusion through gas film controls
(c) when diffusion through ash layer controls
(d) when none of the above applies.

(ix) Slurry phase reactor is used to carry out
(a) Conversion of NO to NO_2
(b) Coal gasification
(c) Hydrocracking of heavy oil
(d) None of above.

(x) Ion exchange bed is a fluid-solid reactor with
(a) continuous counter current operation
(b) continuous co- current operation
(c) batch operation
(d) semi-batch operation.

Group – B

2. (a) (i) Discuss in details the principle of homogeneous catalysis. How the intrinsic kinetic constants are evaluated?

(ii) Define autocatalytic reaction. Prove that the reaction rate in such case follows a parabola with a maximum where concentration of A and R is equal.

(b) Discuss in details the general methods of catalyst preparation

4 + 4 + 4 = 12

3. (a) How the surface area of catalyst is estimated by BET method?

(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 0^0C and 1 atm)	103	116	130	148	159	163	188	198	221	270	294	316	365

Estimate the surface area for this catalyst.

5 + 7 = 12

Group – C

4. (a) Discuss in details various factors affecting the rate of a gas phase reaction catalysed by a solid porous catalyst.

(b) The catalytic reaction $A \rightarrow 4R$ is run at 3.2 atm and 117°C in a plug flow reactor which contains 0.01 kg of catalyst and uses a feed consisting of the partially converted product of 20 liters/hr of pure unreacted A. The results are as follows:

Run	1	2	3	4
C_{Ain}, mol/liter	0.100	0.080	0.060	0.040
C_{Aout}, mol/liter	0.084	0.070	0.055	0.038

Find a rate equation to represent this reaction.

5 + 7 = 12

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

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

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/hr of 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.

(b) (i) Prove that for a first order gas reaction $A \rightarrow R$, carried out under pore diffusion limitation in presence of a single porous catalyst pellet cylindrical in shape:

Effectiveness factor$(\eta) = \frac{\tanh mL}{ml}$, where mL is the Thiele modulus

(ii) 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}) = $\frac{E_{True}}{2}$.

5 + (4 + 3) = 12

Group – D

6. (a) Obtain the equation relating time versus conversion in case of non-catalytic gas-solid reaction according to shrinking core model (spherical particle, unchanging size) where diffusion through gas-film is controlling.

(b) Calculate the time needed to burn to completion particles of graphite (initial radius=5 mm, density of graphite particle = 2.2 gm/cm^3, first order rate constant for surface reaction= 20 cm/sec) in a 9% oxygen stream.

For the high gas velocity used, assume that film diffusion does not offer any resistance to transfer and reaction. Reaction temperature = 900^{0}C.

6 + 6 = 12

7. (a) Mention various steps those occur during gas-solid reaction according to shrinking core model of unchanging size.

(b) A solid feed consisting of the following sized particles:

25 wt% of 1 mm particles and smaller

35 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 3mm particles.

Find the mean conversion of the solids for a residence time of 45 minutes.

4 + 8 = 12

Group – E

8. (a) Give an example of a fluid-fluid reaction.

(b) Define the following:
(i) Liquid film enhancement factor.
(ii) Hatta Number.

(c) Gaseous A absorbs and reacts with B in liquid according to
A (g→l) + B (l) →R (l) $-r_A = kC_AC_B$
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= 10^5 Pa. m^3 liquid/mol.
At a point in the reactor where p_A= 100 Pa and C_B = 100 mol/ m^3 liquid,
(i) Calculate the rate of reaction in mol/hr. m^3 of reactor
(ii) Location of major resistance.

1 + (2 + 3) + 6 = 12

9. (a) Obtain the RTD function for an ideal CSTR following a pulse tracer input.

(b) Suppose a real CSTR has been modelled using bypassing and dead space. For the first order reaction, A→B, derive the expression of conversion in terms of model parameters.

3 + 9 = 12

Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTI2NTM5MTg1NjE3/a/MjY0NDQ4NzE1NDQ1/details