Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (CHE-NEW)/SEM-5/CHE-504/2010-11

2010-11
CHEMICAL REACTION ENGINEERING

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.

GROUP – A
(Multiple Choice Type Questions)

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

i) For a second order reaction, the rate constant is

a) a pure number and has no unit

b) S^{-1}

c) $m^3/k\ mol-s$

d) $k\ mol/m^3-s$.

ii) For the gaseous reaction $A \rightarrow 3B$, where the feed consists of 50 mole% A and 50 mole% inerts, the expansion factor (ε_A) is

a) 1 b) – 0·25

c) – 0·5 d) – 0·75.

iii) The Damkohler number is given by

a) rate of reaction of a reactant/rate of diffusion of reactant to catalyst surface

b) rate of reaction of reactant/ rate of convective transport of reactant at the reactor entrance

c) rate of convective transport of a reactant/rate of reaction of a reactant

d) rate of diffusion of a reactant/rate of convection.

iv) 20 plug flow reactors with a total volume V connected in series gives

a) same conversion as a single plug flow reactor of volume V

b) plug flow reactor of volume 20 V

c) plug flow reactor of volume V/20

d) same conversion as a single mixed flow reactor of volume V.

v) A small value of Thiele modulus in a first order solid catalyzed reaction implies

a) pore diffusion offers very high resistance to reaction

b) pore diffusion offers negligible resistance to reaction

c) effectiveness factor is almost equal to 1

d) both (a) and (c).

vi) For the reaction $A \rightarrow R \rightarrow S$, the time required to achieve the maximum concentration of the intermediate R in a mixed flow reactor is given by

a) $\ln(k_2/k_1)/(k_2 - k_1)$ b) $1/\sqrt{k_1 k_2}$

c) $1/k_1 k_2$ d) $\ln(k_2/k_1)$.

vii) The temperature dependence of reaction rate constant (k) by transition state theory is approximately given by

a) $k \alpha e^{-E/RT}$ b) $k \alpha T^{\frac{1}{2}} e^{-E/RT}$

c) $k \alpha T^2 e^{-E/RT}$ d) $k \alpha T e^{-E/RT}$.

viii) The vessel dispersion number for plug flow is

a) 0 b) 500

c) 750 d) ∞.

ix) Chemostast is

a) a reactor for polymerization

b) an equipment used for treating cancer patients

c) a continuous stirred bio-reactor for growth of micro-organisms

d) a special type plug flow reactor.

x) Identify the scientist who has not contributed in the field of reaction engineering :

a) Octave Levenspiel b) J. M. Smith

c) Chowmosky d) Fogler.

xi) A Triclke Bed reactor

a) basically a filter is

b) a continuous stirred reactor

c) a moving bed reactor for petroleum cracking

d) basically a three-phase reactor.

xii) The Monod constant

a) is dimensionally same with rate constant

b) is dimensionally same with cell concentration

c) is a product of rate constant and cell concentration

d) is having data insufficient, cannot be predicted.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Use collision theory to estimate the specific reaction rate in $dm^3/k\ mol\text{-}s$ for the decomposition of HI, which is given by, $2HI \rightarrow H_2 + I_2$. Assume that the collision diameter σ = 3·5° A and employ the activation energy of 44 k cal/mol determined experimentally. Also evaluate the frequency factor. The molecular weight of hydrogen iodide is 128, the temperature of decomposition is 320° C.

3. At present, conversion is 2/3 for the elementary second order reaction $2A \rightarrow 2R$ when operating in an isothermal plug flow reactor with a recycle ratio of unity. What will be the conversion when the recycle stream is shut off ?

4. Explain how the BET method can be used to estimate the surface area of a catalyst.

5. Prove that for a 2nd order irreversible bimolecular reaction, A + B $\rightarrow$ products in $\frac{M - X_A}{M(1 - X_A)} = C_{AO}(M-1)kt$

   where, M = C_{BO}/C_{AO} & M# 1 (Symbols stand for usual notations).

6. a) State the difference between the molecularity and order of a reaction with an example. 2

   b) In a certain chemical reaction the half-life becomes doubled when the concentration is doubled. Find the order of the reaction. 3

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) For the decomposition A → R in a batch reactor, the different initial concentrations and half-life periods for few experimental runs are noted as

$C_{A0}\ (k\ mol/m^3)$	10	18·5	30
$t_{1/2}(sec)$	100·0	54·0	33·3

Predict the order of the reaction and the rate constant. 5

b) The gas phase reaction 3A → 2B is carried out in a batch reactor. The reactor was initially filled with pure 'A' at 2 atmospheric pressure. After 120 seconds the total pressure in the reactor decreased to 1·5 atmosphere. If the reaction follows 2nd order kinetics, calculate the reaction rate constant. The reaction temperature is 300° C. 10

8. a) Show that for *N*-plug flow reactors in series with a total volume *V* gives the same conversion as a single plug flow reactor of volume *V*.

b) In a variable volume batch reactor a gas phase reaction 2A → B is carried out. Initial concentration of the reactant contents 20% inerts. The reaction follows second order kinetics. Find an expression for the reaction time.

c) The elementary liquid phase reaction $A + 2B \underset{K_2}{\overset{K_1}{\rightleftharpoons}} R$ with rate equation $-r_A = -\frac{1}{2} r_B = \left(12 \cdot 5 \text{ liter}^2/\text{mol}^2 \text{ min}\right)$

$$C_A C_B^{\,2} - \left(1 \cdot 5 \text{ min}^{-1}\right) C_R \text{ mol/(liter min)}$$

is to take place in a 6 liter steady sate mixed flow reactor. Two feed streams, one containing 2·8 mol A/liter and the other containing 1·6 mol B/liter, are to be introduced at equal volumetric flow rates into the reactor and 75% conversion of limiting component is desired. What should the flow rate of each stream ? Assume a constant density throughout. 4 + 5 + 6

9. The first order reaction A → B is carried out in a 10 cm diameter tubular reactor 6·36 m in length. The specific reaction rate is 0·2 min^{-1} the results of a tracer test carried out on this reactor are

t (min)	→	0	1	2	3	4	5	6	7	8	9	10	12	14
c (mg/l)	→	0	1	4	9	10	7	6	4	3	2·2	1·5	0·6	0

Calculate conversion using the tank-in-series model.

10. a) Deduce the mechanistic model for simple enzyme kinetics using quasi-steady state assumption proposed by Briggs and Haldane. Also state the limitation of this assumption. 5 + 1

b) At room temperature sucrose is hydrolyzed by the catalytic action of the enzyme sucrose as follows :

$$\text{socrose} \xrightarrow{\text{sucrase}} \text{products}$$

Starting with a sucrose concentration $C_{A0} = 1{\cdot}0$ millimol/litre and an enzyme concentration $C_{E0} = 0{\cdot}01$ millimol/litre, the following kinetic data are obtained in a batch reactor (concentrations calculated from optical rotation measurements) :

C_A, millimol /litre	0·84	0·68	0·53	0·38	0·27	0·16	0·09	0·04	0·018	0·006	0·0025
t, hr	1	2	3	4	5	6	7	8	9	10	11

Determine whether these data can be reasonably fitted by a kinetic equation of the Michelis-Menten type, or $-r_A = \dfrac{k_3 C_A C_{E0}}{C_A + M}$ where M = Michaelis constant.

If the fit is reasonable, evaluate the constants k_3 and M. Use integral Method. 9

11. a) Explain the difference between holding time and space time for flow reactors with example. Can the two be identical ? Explain with example. 5

b) The catalytic reaction A → 4R is run at 3·2 atm and 117° C in a plug flow reactor which contains 0·01 kg catalyst and uses a feed consisting of the partially converted product of 20 litre/hr of pure unreached A. The results are as follows :

Run	1	2	3	4
C_A, in, mol/litre	0·100	0·080	0·060	0·040
C_A, out, mol/litre	0·084	0·070	0·055	0·038

Find a rate equation to represent this equation. 10