Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(CHE)(N)/SEM-5/CHE-502/2012-13

2012

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) The dimensions of rate constant for reaction $A \rightarrow B$ are (litre/gmole)/min. The reaction order is

a) one b) two

c) three d) zero.

ii) Arrhenius equation shows the variation of ..... with temperature.

a) Reaction rate b) Rate constant

c) Energy of activation d) Frequency factor.

iii) Catalytic action in a catalytic chemical reaction follows from the ability of catalyst to change the

a) activation energy b) equilibrium constant

c) heat of reaction d) none of these.

iv) For the reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ 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 these.

v) The units of frequency factor in Arrhenius equation

a) is same as that of the rate constant

b) is different from the units of the rate constant

c) is unit less

d) none of these.

vi) Which of the following is a characteristic of an elementary reaction ?

a) The molecularity and order of the reaction is the same

b) The reaction rate constant is zero

c) The rate of the reaction is constant

d) The order of the reaction is always 1.

vii) For any reaction, we may write conversion as a function of

a) time b) temperature

c) concentration d) all of these.

viii) 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 these.

ix) Under strong pore diffusion regime an n th order reaction behaves like a

a) $\frac{(n+1)}{2}$ order reaction b) $\frac{(n-1)}{2}$ order reaction

c) zero order reaction d) n th order reaction.

x) What will be the conversion, if we use a single PFR volume V instead of N number of PFR connected in series combination with a total volume of V ?

a) Less b) Equal

c) More d) None of these.

xi) Unreacted core model represents the reaction involving

a) combustion of coal

b) roasting of sulfide ores

c) carbon disulphide manufacturing

d) none of these.

xii) For an autocatalytic reactor, for conversion up to the maximum rate, the suitable reactor set up is

a) CSTR b) PFR

c) recycle reactor d) CSTR followed by PFR.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following $3 \times 5 = 15$

2. At 500 K the rate of a bimolecular reaction is ten times the rate at 400 K. Find the activation energy of this reaction :

   a) From Arrhenius' law

   b) From Collision theory.

3. Write any *two* of the following : $2 \times 2\frac{1}{2}$

   i) Space time and Space volume

   ii) Significance of Residence Time Distribution

   iii) Derive the mathematical expression for rate constant of *n* th order reaction

   iv) Limitations of shrinking core model.

4. Derive the expression of rate of a 2nd order irreversible biomolecular reaction ($A + B \rightarrow R$).

5. Prove that for a second order irreversible bimolecular reaction $A + B \rightarrow$ Products, $\ln(M - X_A)/M(1 - X_A) = C_{A0}(M - 1)Kt$ where $M = C_{B0}/C_{A0}, M \neq 1$ (Symbols have their usual meaning).

6. Find the first order rate constant for the disappearance of *A* in the gas reaction $2A \rightarrow R$ if, on holding the pressure constant, the volume of the reaction mixture is starting with 80% *A* decreases by 20% in 3 min.

GROUP – C

(Long Answer Type Questions)

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

7. a) Obtain the half-life period for a first order isothermal constant volume reaction.

b) A reaction $A \rightarrow P$ is carried out in batch reactor at different initial concentrations. Half-life for each run is noted. Calculate order of reaction and the rate constant from the half-life data given in table below :

$C_{A0}\,(\text{kmol/m}^3)$	10	18·5	30
$t_{1/2}(s)$	100·0	54·0	33·3

c) For the reaction in series $A \xrightarrow{k_1} R \xrightarrow{k_2} S$ carried out in a batch reactor. Prove that slowest step is the rate determining step. 3 + 8 + 4

8. a) The primary reaction occurring in homogeneous decomposition of nitrous oxide is found to be $N_2O \rightarrow N_2 + \frac{1}{2}O_2$ with rate $-r_{H_2O} = K_1[N_2O]^2/1 + K_2[N_2O]$.

Derive a mechanism to explain this observed rate.

b) The aqueous reaction $A \rightarrow R + S$ proceeds as follows,

Time, min	0	36	65	100	160	∞
C_A mol/litre	0·1823	0·1453	0·1216	0·1025	0·0795	0·0494

$C_{A0} = 0 \cdot 1823$ mol/lit, $C_{R0} = 0$, $C_{S0} = 55$ mol/lit, $M = C_{R0} / C_{A0}$ Derive the rate equation to represent the reaction. 7 + 8

9. a) Deduce the performance equation of a recycle reactor.

b) At 600K, the gas phase reaction $C_2H_4 + Br_2 \underset{k_2}{\overset{k_1}{\rightleftharpoons}} C_2H_4Br_2$

has rate constant $k_1 = 500$ litre/mol.hr and $k_2 = 0 \cdot 032\,\text{hr}^{-1}$.

If a plug flow reactor is to be fed $600\,\text{m}^3$/hr of gas containing 60% Br_2, 30% C_2H_4 and 10% inerts by volume at 600K and 1·5 atm compute the volume of reactor vessel required to obtain 60% of the maximum conversion. 5 + 10

10. a) After 8 min in a batch reactor, reactant (C_{A0} = 1 mol/lit) is 80% converted, after 18 min conversion is 90%. Find the rate equation to represent this reaction.

b) At 649°C phosphine (PH_3) decomposes as follows : $4PH_3 \longrightarrow P_4(g) + 6H_2; -r_{PHOS} = (10hr^{-1})C_{PH_3}$. What size of plug flow reactor operating at 649°C and 4·6 atm pressure is needed for 75 per cent conversion of 10 mol/ltr of feed contain 50 per cent phosphine (PH_3) and rest inert. Feed rate is 1·86 kg mol/hr. Determine the size of PFR. 5 + 10

11. a) What is the expression for 'Dispersion number' ? What will be its value for PFT and MFR ?

b) For reactions other than first order, knowledge of the RTD is not sufficient to predict conversion. What is the other parameter ? Why first order reaction need not this parameter ?

c) Write down the names of different models of a real reactor according to the number of adjustable parameters that are extracted from RTD data. 5 + 5 + 5

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