(b) A and B react with each other as follows:

$2A \rightarrow R, \quad r_R = k_1 C_A^2$

$A + B \rightarrow S, \; r_S = k_2 C_A C_B$

$2B \rightarrow T, \quad r_T = k_3 C_B^2$

What ratio of A and B should be maintained in a mixed flow reactor so as to maximize the fractional yield of desired product S?

6 + 6 = 12

7. (a) Kinetic experiments on the solid catalyzed reaction $A \rightarrow 3R$ are conducted at 8 atm and 700°C in a basket type mixed reactor 960 cm^3 in volume and containing 1 gm of catalyst of diameter, d = 3 mm. Feed consisting of pure A is introduced at various rates into the reactor and the partial pressure of A in the exit stream is measured for each feed rate. The results are as follows:

Feed rate, liter/hr	100	22	4	1	0.6
$P_{Aout}//p_{ain}$	0.8	0.5	0.2	0.1	0.05

Find a rate equation to represent the rate of reaction on catalyst of this size.

(b) Explain the various factors which may intrude on the overall rate in case of heterogeneous catalytic reaction on porous solid catalyst pellets.

8 + 4 = 12

Group – E

8. Deduce a suitable RTD zero parameter model of a PFR

12

9. A sample of the tracer hytane at 320K was injected as a pulse to a reactor, and the effluent concentration was measured as a function of time, as per the data shown in the following table.

t (min)	0	1	2	3	4	5	6	7	8	9	10	12	14	17	20	23
C (g/m^3)	0	1	5	8	10	12	11	9	8	6.5	5	3.0	2.2	1.5	0.6	0

Construct figures showing C(t) and E(t) as functions of time.

Determine the fraction of material leaving the reactor that has resided between 7 and 17 minutes.

4 + 5 + 3 = 12

CHEMICAL REACTION ENGINEERING
(CHEN 3102)

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) For the reaction $NO + ½ O_2 = NO_2$ carried out in presence of Pt-Rh 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) From the Arrhenius law the frequency factor
(a) does affect the temperature sensitivity of a reaction
(b) does not affect the temperature sensitivity of a reaction
(c) is dimensionless
(d) is a measure of activation energy.

(iii) A given reaction is much more temperature sensitive at
(a) low temperature (b) high temperature
(c) all temperature levels (d) none of the above.

(iv) If the metabolic activity of a human being is represented by a first order reaction, the magnitude of rate constant will be in terms of
(a) $(nano\text{-}sec)^{-1}$ (b) $m^3/kmol\text{-}sec$
(c) $(day)^{-1}$ (d) $m^6/kmol^2\text{-}sec$.

(v) 1 liter / sec of gaseous reactant A is introduced into a mixed flow reactor having volume 4 liters. The stoichiometry is $A \rightarrow 3R$. The conversion is 50%, and under these conditions the residence time is
(a) 1 sec (b) 2 sec
(c) ½ sec (d) none of the above.

(vi) 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.

(vii) A tricle Bed reactor is a _____ type reactor.
(a) PFR (b) CSTR
(c) three phase packed bed (d) membrane module

(viii) In RTD Analysis the variance is considered as
(a) first moment (b) second moment
(c) extent of maximum mixedness (d) bye-passing.

(ix) In reactor modelling with RTD system, the number of parameters cannot be
(a) zero (b) one
(c) two (d) three.

(x) The Karlovitz number is reciprocal of the
(a) Reynold's number (b) Mach number
(c) Sherwood number (d) Damköhler number.

Group – B

2. (a) The primary reaction occurring in the homogeneous decomposition of nitrous oxide is found to be

$$N_2O \rightarrow N_2 + \tfrac{1}{2} O_2 \text{ with a rate } -r_{N_2O} = \frac{k_1 C_{N_2O}^2}{1 + k_2 C_{N_2}}$$

Devise a suitable mechanism to support this rate equation.

(b) Milk is pasteurized if it is heated to 63^{0}C for 30 min, but if it is heated to 74°C it only needs 15 s for the same result. Find the activation energy of this sterilization process.

6 + 6 = 12

3. A small reaction bomb fitted with a very sensitive pressure-measuring device is flushed out and then filled with pure reactant A at one atmosphere pressure. The operation is carried out at 298K, at which the reaction does not proceed to any appreciable extent. The temperature is then rapidly increased to 373 K by plunging the bomb into boiling water and the following total pressure data are obtained.

t, min	1	2	3	4	5	6	7	8	9	10	15	20
Total pressure,P, atm	1.14	1.04	0.982	0.94	0.905	0.87	0.85	0.832	0.815	0.8	0.754	0.728

The stoichiometry of the reaction is $2A \rightarrow R$. After leaving the bomb in the bath for a period of one week the contents are analyzed for A and no A is detected. Find a rate expression which fits the data satisfactorily. Assume the gas behaves ideally.

12

Group – C

4. The homogeneous reaction $A \rightarrow R$ is being carried out in a flow reactor system has the following rate law,

$$-r_A = \frac{kC_A}{(1 + K_A C_A)^2}$$

where, k = 1 min^{-1} and K_A = 1 dm^3/min
The entering concentration of A is 2 mol/dm^3. What type of reactor or combination of reactors would have the smallest volume to achieve 80% conversion? What will be the volume of each reactor if the initial flow rate of A is 200 mol/min.

12

5. One hundred moles of A per hour are available in a concentration of 0.1 mole/lit by a previous process. This stream is to be reacted with B to produce R and S. The reaction proceeds by the aqueous phase elementary reaction,

A + B = R + S, k = 5 lit/ mo.hr

The amount of R required is 95 mol /hr. In extracting R from the reaction mixture A and B are destroyed, hence recycle of unused reactants is out of the question. Calculate the optimum reactor size and type as well as feed composition for this process.
Data: B costs $ 1.25/mol in crystalline form. It is highly soluble in the aqueous solution and even present in large amounts does not change the concentration of A in solution. Capital and operating costs are $ 0.015/hr.lit. for PFR and $ 0.004/hr.lit for MFR.

12

Group – D

6. (a) A 20 liter MFR is to treat a reactant which decomposes as follows

$A \rightarrow R$, $r_R = 4hr^{-1}C_A$
$A \rightarrow S$, $r_S = 1hr^{-1}C_A$

Find the feed rate and conversion of reactant so as to maximize profits. What are these on an hourly basis?
Data: Feed material A costs \$1/mol at C_{A0} = 1 mol/lit, product R sells for \$5/mol and s has no value. The total operating cost of reactant and product separation equipment is \$25/hr + \$1.25/mol A feed to the reactor. Unconverted A is not recycled.