and 85% conversion of lactose is required. Find the volume of the rector needed. The system follows Michaelis- Menten equation having k_3 and K_m 5.37 min^{-1} and 195.2 kg/m^3 respectively. The initial enzyme concentration is 0.3 kg/m^3.

6 + 6 = 12

7. (a) Deduce the performance equation of chemostat used for conducting enzymatic reaction.

(b) The following data have been obtained for two different initial enzyme concentrations for an enzyme - catalyzed reaction.

Substrate concentration,(gm / liter)	20.0	10.0	6.7	5.0	4.0	3.3	2.9	2.5
Rate (g/l-min) with C_{E0}= 0.015 gm/liter	1.14	0.87	0.70	0.59	0.50	0.44	0.39	0.35
Rate (g/l-min) with C_{E0}= 0.00875gm/liter	0.67	0.51	0.41	0.34	0.29	x	x	x

Find the intrinsic kinetic parameters of Michaelis and Menten equation by Hanes – Woolfs method.

4 + 8 = 12

Group – E

8. (a) Deduce an energy balance equation relating moles of limiting reactant converted and temperature for a second order reaction carried out in a batch reactor. Use simplified assumptions.

(b) The ideal gas decomposition $A \longrightarrow B + C$ takes place with initial conditions 333 K, 5 atm and 0.25 m^3. The enthalpy change of reaction is – 5830 KJ/kg at 330 K, the heat capacity of A is 126 KJ/Kmol.K and those of B and C are each 105 KJ/kmol.K. Calculate the time required for 85% conversion A if the reaction is carried out adiabatically.

Data:

T,K	330	356	362	368	373	380	384
k, s^{-1}	4.32	6.05	8.39	11.81	16.60	25.90	33.90

6 + 6 = 12

9. A batch reactor has a 230 kg charge of a solution of acetic anhydride at 15.5°C containing acetic anhydride at a concentration of 0.22 kmol/m^3. The solution density is 1048 kg/m^3 and its specific heat 0.9kcal/(kg)(°C). The first order reaction has ΔH = -50,000 kcal/kmol of anhydride hydrolysed. Find the time for 80% conversion under adiabatic condition.

Data:

Temperature, ^{0}C	4.44	10	15.5	21.11	26.7	32.2
Rate constant, k, min^{-1}	0.035	0.057	0.084	0.123	0.174	0.245

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REACTOR DESIGN
(CHEN 4141)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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) The plot of rate versus substrate concentration of an enzymatic reaction gives a section of rectangular hyperbola. The system represents a:
(a) shifting order reaction (b) first order reaction
(c) zero order reaction (d) none of the above.

(ii) For a mixed flow reactor operating at steady state under variable volume condition:
(a) space time is equal to residence time
(b) space time and residence time are different
(c) only under special condition space time is equal to residence time
(d) none of the above.

(iii) For a substrate uninhibited enzymatic reaction the reaction rate versus substrate concentration plot gives:
(a) a linear plot (b) a parabola
(c) a section of rectangular hyperbola (d) none of the above.

(iv) 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.

(v) Michaelis Mentane theory is based upon:
(a) steady state theory
(b) equilibrium condition
(c) combination of steady state and equilibrium condition
(d) none of the above.

(vi) What is the dispersion number for a CSTR?
(a) 0 (b) 1 (c) <1 (d) ∞.

(vii) Chemostat is:
(a) a steady state reactor (b) an unsteady state reactor
(c) is always operated at isothermal condition (d) none of the above.

(viii) The rate constant at 500°K and 400°K is 2, if Arrhenius law is used. What will be this ratio, if transition state theory is used with the same value of E/R?
(a) 1.6 (b) 2 (c) 2.24 (d) 2.5.

(ix) If the slope of the heat removal line is greater than the greatest slope of the heat generation curve there will be
(a) only one intersection of the heat removal line and the heat generation curve
(b) two intersections of the heat removal line and the heat generation curve
(c) no intersection of the heat removal line and the heat generation curve
(d) multiple intersections (more than two) of the heat removal line and the heat generation curve.

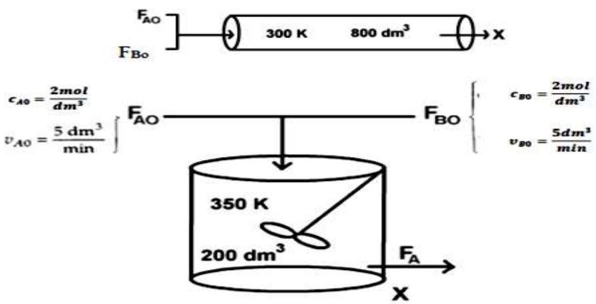
(x) A catalytic fluidized bed reactor is most suitable:
(a) for an isothermal reaction (b) for a reaction with heat effect
(c) for a homogeneous reaction (d) none of the above.

Group – B

2. The elementary, liquid-phase, irreversible reaction $A + B \rightarrow C$ is to be carried out in a flow reactor. Two reactors are available, an 800 dm^3 PFR that can only be operated at 300 K and a 200 dm^3 CSTR that can be operated at 350 K. The two feed streams to the reactor mix to form a single feed stream that is equal molar in A and B, with a total volumetric flow rate of 10 dm^3/min. Which of the two reactors will give us the highest conversion?

Assumptions: (i) Isothermal, no pressure drop, (ii) The CSTR is well mixed. There are no radial variations in the PFR.

Additional Information:
at 300 K, $k = 0.07$ dm^3/mol-m
E=85000J/mol-K
$C_{A0}=C_{B0}=2$mol/dm^3
$v_{A0} = v_{B0} = 0.5v_0 = 5$ dm^3/min



12

3. (a) The reaction $A \rightarrow B$, $r = kC_A$ occurs in an n equal volume CSTRs in series each with residence time τ, with 90% overall conversion. If $k = 0.5$ min^{-1}, $C_{A0} = 2$ moles/litter, and $v = 4$ litter/min, what residence times and reactor volumes will be required for n= 1, 2, and 3?

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

$C_{A0}(\frac{kmol}{m^3})$	12	17.5	32
$t_{1/2}$(sec)	108	56	34.3

6 + 6 = 12

Group – C

4. At 700°C the rate of decomposition A → 3R, on a specific catalyst of given size is found to be

$$-r_A' = -\frac{1}{w}\frac{dN}{dt} = 10\ \frac{liter}{gmcat.hr}\ C_A$$

A pilot plant is to be built. This is to be a tubular packed bed 2 cm ID using 25% of these active catalyst pellets evenly mixed with 75% inert pellets to insure isothermal operations. For 400 mol / hr feed consisting of 50% A – 50% inert gas at 8 atm and 700°C what must be the length of reactor so that $p_{Aout}/p_{Ain} = 0.111$.
Data: catalyst and inert pellets are porous, of diameter d_p = 3 mm, particle density = 2 gm/cm^3. Bulk voidage of packed bed = 50%

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5. A West Texas gas oil is cracked in a tubular reactor packed with silica-alumina cracking catalyst. The liquid feed (mw = 255) is vaporized, heated, enters the reactor at 630°C and 1 atm, and with adequate temperature control stays close to this temperature within the reactor. The cracking reaction follows first-order kinetics and gives a variety of products with mean molecular weight mw = 70. Half the feed is cracked for a feed rate of 60 m^3 liquid/m^3 reactor. hr. In the industry this measure of feed rate is called the liquid hourly space velocity. Thus LHSV = 60 hr^{-1}. Find the first-order rate constants k' and k‴ for this cracking reaction.
Data: Density of liquid feed: p_l = 869 kg/m^3
Bulk density of packed bed: p_s = 700 kg/m^3
Density of catalyst particles: p_s = 950 kg/m^3

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Group – D

6. (a) Deduce the performance equation of batch fermenter used for conducting enzymatic reaction.

(b) It is desired to convert 10 tonnes lactose/day in a batch reactor using β-galactosidase enzyme. The plant operates day and night and the times for filling , cleaning and emptying the reactor are 0.45 hours. The initial concentration of lactose is 150 kg/m^3