Question Paper

Exam Date & Time: 24-Apr-2019 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

CHEMICAL REACTION ENGINEERING [ICHM 241 - S2]

Marks: 100 **Duration: 180 mins.**

Answer 5 out of 8 questions.

1) A) At 500K the rate of a bimolecular reaction is ten times the rate of at 400K. Find the activation energy for this reaction by using (10)

- Arrhenius law
- Transition state theory
- Collision theory

Determine the % difference in rate of reaction at 600K predicted by these methods.

B) Prove that the above following mechanism can explain the first order decomposition of substrate A. (10)

$$A \leftrightarrow P + Q^*$$

$$Q^* \rightarrow R^* + S$$

$$R^* + Q^* \rightarrow 2P$$

A is a substrate, P & S are products, R* & Q* are intermediates.

2) A) For a single substrate-enzyme reaction (Michaelis and Menten) propose a mechanism and derive an expression for the rate of product formation: (10)

B) Reactant A decomposes in a batch reactor A → Products. The composition of A in the reactor is measured at various times. Find a rate equation to represent the data by differential method. (10)

Time(sec)	0	20	40	60	120	180	300
C_A (mol/L)	10	8	6	5	3	2	1

3) A) Thermal decomposition of dimethyl ether in the gas phase ($CH_3OCH_3 \rightarrow CH_4 + CO + H_2$) was studied by measuring the increase in pressure in a constant volume reactor. The reactor was initially filled with pure ether and the reactor initial pressure was 312 mmHg. From the following data, determine the (10)

reaction rate constant and order.

Time(sec)	390	777	1195	3155
Rise in pressure , mmHg	96	176	250	476

B) Derive an expression for residence time in a PFR for a gas phase second order reaction: (10)

4) A) We are planning to operate a batch reactor to convert A into R. This is a liquid reaction, the stoichiometry is $A \rightarrow R$, and the rate of reaction is given in Table. How long must we react each batch for the concentration to drop from C_{Ao} = 1.3 mol/L to C_{Af}= 0.3 mol/L? (10)

CA, mol/L	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1	1.3	2
$-r_A$, (mol/L min)	0.1	0.3	0.5	0.6	0.5	0.25	0.1	0.06	0.05	0.045	0.042

B) Enzyme E catalyzes the fermentation of substrate A (the reactant) to product R. The kinetics of the fermentation at this enzyme concentration are given by, (10)

$$A \xrightarrow{\text{enzyme}} R, \qquad -r_A = \frac{0.1\, C_A}{1 + 0.5\, C_A} \; \frac{\text{mol}}{\text{liter} \cdot \text{min}}$$

Find the size of the reactor needed for 95% conversion of reactant in a feed stream (25 liter/min) of reactant (2 mol/liter) and enzyme for the following cases:

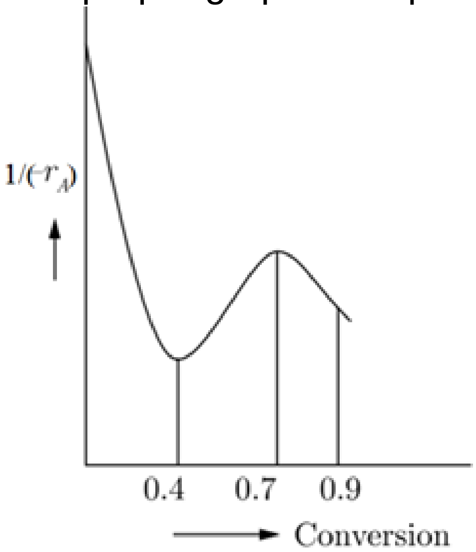
- MFR
- PFR

5) A) 1 L/sec of a 20% ozone + 80% air mixture at 1.5 atm and 93°C passes through a PFR. Under these conditions ozone decomposes by homogenous reaction, $2O_3 \rightarrow 3\ O_2$, $-r_{ozone} = k\, C_{ozone}^2$, k = 0.05 L/mol sec). What size of the reactor is needed for 50% decomposition of ozone? (10)

B) A noble metal (catalyst) was trapped in 8 mm diameter agarose beads at a concentration of 0.018 kg metal m^{-3} gel. The beads were immersed in a well-mixed solution containing 3.2×10^{-3} (10)

kg/m^3 substrate. The effective diffusivity of substrate in agarose gel is 2.1×10^{-9} m^2/s. Kinetics of the reaction can be approximated as first order with specific rate constant 3.11×10^5 s^{-1} per kg metal. Mass transfer effects outside the particles are negligible. Plot the steady-state substrate concentration profile as a function of particle radius.

6) A) A liquid phase reaction is to be carried out under isothermal conditions. From the following data, what choice of reactor or combination of reactors will require the minimum overall reactor volume, if a conversion of 90% is desired? Justify your choice with proper graphical representations / analytical expressions: (10)



B) A harmful component A is present in an industrial wastewater degrades into harmless chemicals in the presence of an enzyme E which acts as a homogeneous catalyst. Following laboratory results were obtained using MFR for a given enzyme concentration: (10)

C_{Ao} (m mol/m^3)	2	5	6	6	11	14	16	24
C_A (m mol/m^3)	0.5	3	1	2	6	10	8	4
τ (min)	30	1	50	8	4	20	20	4

It is desired to treat 0.1 m^3/min of this wastewater with C_{Ao} = 10 m mol/m^3 to 90% conversion with enzyme E at concentration C_E. Determine the arrangement of two reactors in series which minimize the total volume:

7) For a spherical catalyst with first order reaction derive an expression for the following: (20)

- Concentration profile inside the catalyst
- Observed reaction rate

8) By using the following Thiele modulus parameter expression, (20)

$$\phi = \frac{V_p}{S_x}\frac{(-r_A)\big|_{C_{As}}}{\sqrt{2}}\left\{\int_0^{C_{As}} D_{Ae}(-r_A)\,dC_A\right\}^{-1/2}$$

Derive an expression for the Thiele modulus parameter for the following cases:

- Spherical catalyst, first order reaction
- Spherical catalyst, zero order reaction
- Flat plate catalyst, first order reaction
- Flat plate catalyst, zero order reaction

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