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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Fifth semester B.Tech degree examinations (S) September 2020

Course Code: CH305

Course Name: CHEMICAL REACTION ENGINEERING - I

Max. Marks: 100 Duration: 3 Hours

PART A

Answer any two full questions, each carries 15 marks. Marks

1 a) The stoichiometry and kinetics of the fermentation reaction are given by: (3)

$$A \rightarrow R, -r_A = \frac{2C_A^2 + 0.1C_A}{1 + 50C_A}$$

Where C_A is the concentration of reactant and varies in the range 0.5-50 mol/m^3. For very high concentrations of A, determine the reaction order.

b) Derive the equation for temperature dependency from transition theory. Compare different theories for predicting temperature dependency of reaction rate constant. (7)

c) At 1100 K n-nonane thermally cracks (breaks down into smaller molecules) 20 times as rapidly as at 1000 K. Estimate the activation energy for this decomposition from Arrhenius law. (5)

2 a) The thermal decomposition of ethane to ethylene, methane, butane and hydrogen is believed to proceed in the following sequence. Use the PSSH to derive the rate law for formation of ethylene. (10)

$$C_2H_6 \xrightarrow{k1} 2CH_3^*$$

$$CH_3^* + C_2H_6 \xrightarrow{k2} CH_4 + C_2H_5^*$$

$$C_2H_5^* \xrightarrow{k3} C_2H_4 + H^*$$

$$C_2H_6 + H^* \xrightarrow{k4} C_2H_5^* + H_2$$

$$2C_2H_5^* \xrightarrow{k5} C_4H_{10}$$

b) Define pseudo steady state hypothesis. Explain different types of intermediates with examples. (5)

3 a) Experimental analysis shows that the homogeneous decomposition of ozone (2)

($2O_3 \rightarrow 3O_2$) proceeds with a rate $-r_{O3} = k[O_3]^2[O_2]^{-1}$. Devise a two step mechanism to explain this rate.

b) Propose a mechanism for the decomposition of Nitrous oxide ($N_2O \rightarrow N_2 + \frac{1}{2} O_2$) and show that the rate is given by: (5)

$$-r_{N_2O} = \frac{k_1[N_2O]^2}{1 + k'[N_2O]}$$

c) Variation of the rate constant with temperature for the reaction (8)

$$2N_2O_5 \rightarrow 2N_2O_4 + O_2$$

is given in the following table.

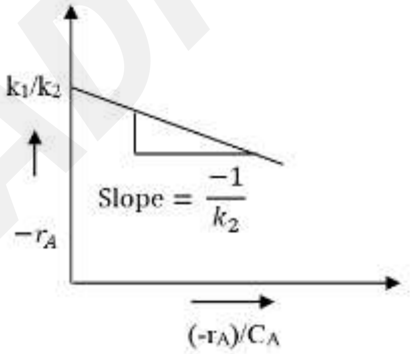
Temp. (K)	298	308	318	328	338
k (s^{-1})	1.74×10^{-5}	6.61×10^{-5}	2.51×10^{-4}	7.59×10^{-4}	2.40×10^{-3}

Determine graphically, the activation energy for the reaction and frequency factor.

PART B

Answer any two full questions, each carries 15 marks.

4 a) For the figure below, write a suitable rate expression. (3)



b) Derive the kinetics of Autcatalytic reactions. (5)

c) For the liquid phase reaction, A → P, in a series of experiments in a batch reactor, the half-life $t_{1/2}$ was found to be inversely proportional to the square root of the initial concentration of A. Determine the order of the reaction. (7)

5 a) Define Damkohler number. Give its physical significance. Write down Damkohler number for first and second order reactions. (2)

b) An isothermal aqueous phase reversible reaction, A↔R is to be carried out in a mixed flow reactor. the reaction rate in kmol/(m^3.h) is given by: (7)

$$-r_A = 0.5C_A - 0.125C_R$$

A stream containing only A enters the reactor. Determine the residence time required (in hours) for 40% conversion of A.

c) Derive the performance equation for a batch reactor for constant density and variable density systems for a first order irreversible reaction. (6)

6 a) A homogeneous gas phase decomposition reaction 4A → B + 7S takes place in an isothermal ideal plug flow reactor. The reaction rate is, $-r_A = k_1 C_A$ with $k_1 = 0.17\ s^{-1}$; feed concentration of A (C_{Ao}) = 0.1 mol/m^3; Feed Flow rate (F_{Ao}) = 0.17 mol/s. Determine the size of the reactor to achieve 50% conversion (5)

b) Define space time and space velocity. Deduce the integrated rate expression for a zero order reaction in a variable volume batch reactor. (5)

c) Show that the performance of N equal sized CSTR's in series is equivalent to a Plug Flow Reactor (PFR). (5)

PART C

Answer any two full questions, each carries 20 marks.

7 a) Derive Michaelis-Menten kinetic equation for the enzyme catalyzed reaction A→R. (5)

b) With a neat sketch, explain the principle of membrane reactor. (5)

c) Explain the mechanism of non-competitive inhibition in enzyme reactions and obtain the kinetic expression (10)

8 a) A CSTR and a PFR of equal volume V each are given for the conduct of a second order, isothermal, liquid phase reaction, A→B. The reactors are to be arranged in series. Find the overall conversion for the two possible reactor arrangements. (10)

Data given: k = 1 m^3/(kmol.s), C_{A0} = 0.1 kmol/m^3 and τ = 5 s (for volume V).

b) Develop expressions for optimum space time and maximum concentration of product R for a series reaction with first order kinetics ($A \xrightarrow{k1} R \xrightarrow{k2} S$) in a CSTR. Assume that the feed contains no R and S. k_1 and k_2 are first order rate constants. (10)

9 a) The irreversible gas-phase non-elementary reaction, A + 2B → C is to be carried out isothermally in a constant pressure batch reactor. (10)

The feed is at a temperature of 227 ^{0}C, a pressure of 1013 kPa, and its composition is 33.3% A and 66.7% B. Laboratory data taken under identical conditions are as follows:

$-r_A$ (mol/dm^3.s)	0.00001	0.000005	0.000002	0.000001
X	0	0.2	0.4	0.6

Determine: (i) The volume of a plug flow reactor required to achieve 30% conversion of A for an entering volumetric flow rate of 2 m^3/min., (ii) The volume of a CSTR required to take the effluent from the plug flow reactor (PFR) above and achieve 50% total conversion (based on species A fed to the PFR) and (iii) The total volume of the two reactors.

b) Calculate the pressure drop in a 60 ft length of 1.5 in. schedule 40 pipe packed with catalyst pellets 0.25 in. diameter. There is 104.4 lb_m/h of gas passing through the bed. The temperature is constant along the length of pipe at 260^oC. The void fraction is 45% and the properties of gas are similar to air at this temperature. The entering pressure is 10 atm. Assume viscosity of air at 260^oC and 10 atm is 0.0673 $lb_m/ft.h$ and the density of air at 260^oC and 10 atm is 0.413 lb_m/ft^3. The flow area of 1.5 in. schedule 40 pipe is 0.0141 ft^2. (10)

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