INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester 2017-18

Date of Examination : 20.09.2017 ___ Session (FN/AN) FN _ Duration 2 hrs Full Marks: 30 _
Subject No. : CH31009 Subject : REACTION ENGINEERING
Department/Center/School : CHEMICAL ENGINEERING
Specific charts, graph paper, log book etc., required: Graph papers
Special Instructions (if any) : Attempt all questions. Assume the missing parameters.

Q1. A zero order homogeneous gaseous reaction A→ rR takes place in a constant volume bomb, P=1 atm when t=0 and P=1.5 when t=1 min. If the same reaction, same feed composition, and initial pressure takes place in a constant-pressure apparatus, find V at t = 1 min if the initial volume V_0 = 1 liter at t=0

(Where V= volume in liter , P= total pressure in atm and t=time in min) [6]

Q2. A high molecular weight hydrocarbon stream is continuously fed to a mixed flow reactor at high temperature where it thermally cracks into lower molecular weight materials, R, as per the stoichiometry A→ 5R. The reactor volume is V= 0.1 L, and the initial concentration at the reactor temperature is C_{A0}=100 millimol/L. It is homogeneous gas phase reaction. Data obtained by varying the feed rate to the reactor as follows :

F_{A0} , millimol/h	300	1000	3000	5000
$C_{A,out}$, millimol/L	16	30	50	60

Find a rate equation to represent the cracking reaction. [6]

Q3. Why mixed flow reactor requires more reactor volume than plug flow reactor under identical process conditions ? Explain with a figure. [3]

Q4. (a) Write the types of adsorption mechanism which can be assumed for a solid catalytic reaction, A + B→ C (Explain with drawing if required)

(b) Write the expression of the catalyst site balance and the unit of the site concentration for solid catalyst for the above reaction. [3+2]

Q5. How do you physically explain the dependence of rate on the superficial reactant gas velocity and catalyst particle size for a solid catalytic gas phase reaction? [5]

Q6. Determine the rate law for the following surface reaction controlled reaction, S is vacant site of catalyst: A.S +B → C.S [5]

G9

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date: September, 2016 FN/AN, **Time :** 2 Hrs **Full Marks :** 30, **Deptt.** Chemical Engineering
No. of Students :87 Mid Autumn Semester Examination
Subject No : CH31009 **Subject Name :** Reaction Engineering
3rd Yr. B. Tech.(H)/M.Tech(Dual)

Instructions : Attempt all questions. Assume the missing parameters.

PART-A

Q1. Answer the following questions.

(a) For the stoichiometry A + B→ R, find the reaction order with respect to A and B if

C_A	2	2	3
C_B	125	64	64
$-r_A$	50	32	48

(b) Derive a rate equation for the enzyme-substrate reaction

$S + E \leftrightarrows ES$ (assume k_1= forward rate constant, k_{-1}= reverse rate constant)

$ES \xrightarrow{k_2} P + E$ where, $d[ES]/dt = 0$, and $[E_o] = [E] + [ES]$

$[E_o]$ represents the total enzyme and [E] represents the free unattached enzyme. [2+3]

Q2. The gas phase reaction A + 2B → 2D is to be carried out in an isothermal plug-flow reactor at 5.0 atm. The feed contains 20 mole% of A, 50 mole% of B and rest inerts.

(a) Set up a stoichiometric table for the above reaction and express the concentration of each species of the reaction as a function of conversion.

(b) How large must the plug-flow reactor be to achieve a conversion (based on A) of 0.70 if the feed temperature in the reactor is uniform(55°C), the volumetric feed rate is 50 dm^3/min and the rate equation at 55°C is $-r_A = 2.5C_A^{1/2}C_B\ kmol/(m^3.min)$ [4+6]

PART-B

Q3. (a) Toluene (T) disproportionation reaction on zeolite catalyst surface at vapour phase produces benzene (B) and xylene (X) by the following reaction:

$$2T \longrightarrow B + X$$

The surface reaction is irreversible in nature. Assuming reaction as rate controlling step, deduce the rate law and show the nature of relation between initial rate and toluene concentration. The reaction is not influenced by mass transfer resistance.

(b) Which rate kinetics are you following in this deduction? [(3+1) +2=6]

Q4. (a) Derive the expression of mass flux of A for the following mass transfer limited reaction,

$$A \longrightarrow 2B$$

Considering the reaction is happening with resistance to the external mass transfer to a solid catalyst and surface reaction is rate controlling.

(b) Explain properly how the rate of the above type of reaction is dependent on the velocity of the reactant and particle size of the catalyst. [3+6=9]

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date .....FN/AN, **Time :** 2 Hrs **Full Marks :** 30, **Deptt.** Chemical Engineering

No. of Students :89 , Mid Autumn Semester Examination

Subject No : CH31009 **Subject Name :** Reaction Engineering

3rdYr. B. Tech.(Hons)

Instructions : Attempt all questions. Assume the missing parameters.

PART-A

1. (a) Derive an expression for concentration as a function of time in an isothermal batch reactor for the irreversible elementary reaction $A+B \rightarrow R$

   (b) The order of a reaction $A \rightarrow R$ at high concentration of A is 'm' and at a low concentration of A, it is 'n'. Give the reason for this change of order of the reaction and suggest a rate equation for the reaction. [3+2]

2. For the decomposition of nitrous oxide $N_2O \rightarrow N_2 + \frac{1}{2}O_2$, the rate equation is given by

$$-r_{N_2O} = \frac{k_1[N_2O]^2}{1 + k_2[N_2O]}$$

   Propose a mechanism for the reaction and derive the above expression. [5]

3. The solid-catalyzed decomposition of gaseous A proceeds as follows:

   $A \rightarrow R \quad -r_A = k_A C_A^2$

   A tubular pilot plant reactor packed with 2 liters of catalyst is fed 2 m^3/hr of pure A at 300°C and 20 atm. Conversion of reactant is 65%.

   In a larger plant, it is desired to treat 100 m^3/hr of feed gases at 40 atm and 300°C containing 60% A and 40% diluents to obtain 85% conversion of A. Find the reactor volume required. [5]

PART-B

4. Explain with a figure, the nature of the curve of reaction rate with catalyst particle size and gas velocity past the particles in a packed bed-reactor. [4]

5. Derive the rate equation based on dual site mechanism for the following reaction assuming surface reaction is the rate limiting step: $N \rightarrow P$ [6]

6. How do you define effectiveness factor? Write the algorithm for determination of effectiveness factor for a spherical pellet catalyst. Show with a figure the dependence of effectiveness factor on Thiele modulus for different shaped catalysts. [1+3+1=5]

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date .....FN/AN, **Time :** 2 Hrs **Full Marks :** 30, **Deptt.** Chemical Engineering
No. of Students :82, Mid Autumn Semester Examination
Subject No : CH31009 **Subject Name :** Reaction Engineering
3rd Yr. B. Tech.(H)/M.Tech.Dual

Instructions : Attempt all questions. Assume the missing parameters.

PART-A

1. Answer the following questions.

(a) For a gas reaction at 400K the rate is given by $-\frac{dp_A}{dt} = 3.67 p_A^2, atm/hr$. What are the units of rate constant? What will be the value of the rate constant for the same reaction if the rate equation is expressed as $-r_A = -\frac{1}{V}\frac{dN_A}{dt} = kC_A^2 mol/lit.hr$. [2]

(b) On doubling the concentration of reactant, the rate of reaction triples. Find the reaction order. [2]

(c) For the reaction A+B → R (rate equation : $-r_A = k_1 C_A C_B$ *and* $C_{B0}/C_{A0} = 1$), considering an isothermal tubular reactor under plug flow condition, starting from the mass balance equation, derive an equation for volume of the plug flow reactor assuming A as the limiting reactant. [C_{A0} *and* C_{B0} are the initial concentrations of A and B respectively]. [3]

2. At 650°C phosphine vapor decomposes as follows:

$$4PH_3 \rightarrow P_4(g) + 6H_2 \ , \ -r_A = (10 hr^{-1}) C_{PH3}$$

We wish to treat 10 mols/hr of phosphine vapor in a feed containing 2/3-phosphine-1/3-inert.

(a) What size of plug flow reactor operating at 650°C and 11.4 atm is needed to achieve 75% conversion?

(b) What outlet composition would you expect if the plug flow reactor is replaced by the same size of mixed flow reactor and treated with a pure feed of phosphine, at the same operating conditions and space-time of part (a)?

[4+4]

PART-B

3. (a) Write the types of mechanism which can be assumed for a solid catalytic reaction, A + B→ C (Explain with drawing if required).

(b) Write the expression of the catalyst site balance and the unit of the site concentration for solid catalyst for the above reaction.

(c) Explain with a figure how the rate of a solid catalytic reaction is dependent on the velocity of the reactant through the catalyst bed and catalyst particle size.

(d) Determine the rate law for the following surface reaction controlled reaction, S is vacant site of catalyst: A.S +B → C.S [5+2+5+3=15]

GP

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date: September, 2016 FN/AN, **Time :** 2 Hrs **Full Marks :** 30, **Deptt.** Chemical Engineering

No. of Students :87 Mid Autumn Semester Examination

Subject No : CH31009 **Subject Name :** Reaction Engineering

3rd Yr. B. Tech.(H)/M.Tech(Dual)

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PART-A

Q1. Answer the following questions.

(a) For the stoichiometry A + B→ R, find the reaction order with respect to A and B if

C_A	2	2	3
C_B	125	64	64
$-r_A$	50	32	48

(b) Derive a rate equation for the enzyme-substrate reaction

$S + E \leftrightarrows ES$ (assume k_1= forward rate constant, k_{-1}= reverse rate constant)

$ES \xrightarrow{k_2} P + E$ where, d[ES]/dt =0, and $[E_o] = [E] + [ES]$

$[E_o]$ represents the total enzyme and [E] represents the free unattached enzyme. [2+3]

Seagate alignment

Q2. The gas phase reaction A + 2B → 2D is to be carried out in an isothermal plug-flow reactor at 5.0 atm. The feed contains 20 mole% of A, 50 mole% of B and rest inerts.

(a) Set up a stoichiometric table for the above reaction and express the concentration of each species of the reaction as a function of conversion.

(b) How large must the plug-flow reactor be to achieve a conversion (based on A) of 0.70 if the feed temperature in the reactor is uniform(55°C), the volumetric feed rate is 50 dm^3/min and the rate equation at 55°C is $-r_A = 2.5C_A^{1/2}C_B\ kmol/(m^3.min)$ [4+6]

5

6.

PART-B

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The surface reaction is irreversible in nature. Assuming reaction as rate controlling step, deduce the rate law and show the nature of relation between initial rate and toluene concentration. The reaction is not influenced by mass transfer resistance.

(b) Which rate kinetics are you following in this deduction? [(3+1) +2=6]

Q4. (a) Derive the expression of mass flux of A for the following mass transfer limited reaction,

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(b) Explain properly how the rate of the above type of reaction is dependent on the velocity of the reactant and particle size of the catalyst. [3+6=9]

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Propose a mechanism for the reaction and derive the above expression. [5]

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Mid-Autumn Semester 2017-18

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Department/Center/School : CHEMICAL ENGINEERING
Specific charts, graph paper, log book etc., required: Graph papers
Special Instructions (if any) : Attempt all questions. Assume the missing parameters.

PART- A

Q1. (a) For the decomposition of nitrous oxide $N_2O \rightarrow N_2 + \frac{1}{2}O_2$

The following mechanism is proposed:

$$N_2O \rightleftarrows N_2O^*$$

$$N_2O^* + N_2O \rightarrow 2N_2 + O_2$$

k_1, k_2, and k_3 may be used as constants in the above equations. Derive a rate equation for the decomposition of N_2O. [5]

(b) Find the first-order rate constant for the disappearance of A in the gas phase reaction $2A \rightarrow R$ if, on holding the pressure constant in a batch reactor, the volume of the reaction mixture, starting with 80% A, decreases by 20% in 3 min. [5]

Q 2. A mixed flow reactor is being used to determine the kinetics of a reaction whose stoichiometry is $A \rightarrow R$. For this purpose various flow rates(v_0) of an aqueous solution of 100 mmol A/lit are feed to a 1-liter mixed flow reactor, and for each run the outlet concentration of A (C_A) is measured. Find a rate equation to represent the following data. Also assume that the reactant alone affects the rate.

v_0, liter/min	1	6	24
C_A, mmol/lit	4	20	50

[5]

PART-B

Q 3 a) Write the steps involved in a gas phase solid catalytic reaction occurring within the catalyst pores where A and B are the two gaseous reactants and C and D are the products in gas phase.

b) Write the expression of the catalyst site balance and the units of the site concentration.

c) Describe the types of mechanism which can be assumed for above solid catalytic reaction (Show with drawing if required).

(d) Explain properly how the rate of the above type of reaction is dependent on the velocity of the reactant and particle size of the catalyst.

[3+1+3+3=10]

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(b) Which rate kinetic model are you following in this deduction? [(3+1)+1=5]

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(b) On doubling the concentration of reactant, the rate of reaction triples. Find the reaction order. [2]

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[4+4]

PART-B

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[5+2+5+3=15]