INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End-Spring Semester Examination 2022-23

Date of Examination: _____ **Session: (FN/AN)** _____ **Duration: 3 hrs. Full Marks:** 50

Subject No.: CH21206 **Subject:** REACTION ENGINEERING

Department/Center/School: CHEMICAL ENGINEERING

Specific charts, graph paper, log book etc., required

Special Instructions (if any): _____

PART-A

Q1. **[4+4 = 8 marks]**

For the reaction system A → B → C, in a continuous reactor where each reaction is irreversible, liquid phase and possessing first order kinetics, determine,

(a) τ_{max} and Y_{Bmax} in a PFR

(b) τ_{max} and Y_{Bmax} in a CSTR

for the case when yield of B is the maximum by showing proper derivation.

Q2. **[6+6 = 12 marks]**

The elementary irreversible gas-phase reaction

$$A \rightarrow B + C$$

is carried out adiabatically in a PFR packed with a catalyst. Pure A enters the reactor at a volumetric flow rate of 20 dm^3/s at a pressure of 10 atm. pressure and a temperature of 450 K. Assume that $\Delta P = 0.0$

(a) Formulate the conversion and temperature profile down the plug-flow reactor from the starting and find the corresponding equations to be solved. Also write the initial condition.

(b) What catalyst weight is necessary to achieve 80% conversion in a CSTR?

Additional information:

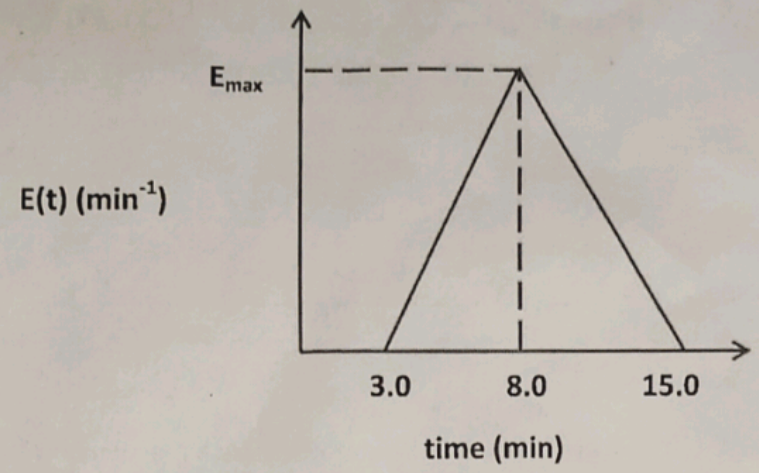
$C_{PA} = 40$ J/mol.K $C_{PB} = 25$ J/mol.K $C_{PC} = 15$ J/mol.K

$H^0_A = -70$ kJ/mol $H^0_B = -50$ kJ/mol $H^0_C = -40$ kJ/mol

All heats of formation are referenced to 273 K.

$k = 0.133 \exp[\frac{E}{R}(\frac{1}{450} - \frac{1}{T})] \frac{dm3}{kg.cat.s}$ *with* $E = 31.4\ kJ/mol$

Q3. [2 + 3 = 5 marks]



The residence time distribution for a real reactor is shown in the above diagram.

(a) What is the value of E_{max}?

(b) What is the value of mean residence time (t_m) in min?

PART-B

Q4. [1 marks]

How can you express mass transfer co-efficient in terms of concentration difference and mole flux for a solid catalytic gas phase reaction?

Q5. [4 marks]

For solid catalytic gas phase reaction, how the rate of the reaction is dependent on the gas phase velocity and catalyst particle size? Explain with logic by proper figure showing control regimes.

Q6. [1 + 4 = 5 marks]

Define "Effective Diffusivity". Write the expression of it explaining all the terms in that.

Q7. [2 marks]

How effectiveness factor is related to Thiele modulus for various shapes of the catalyst?

Q8. [3 marks]

Make a flow diagram for determination of Effectiveness factor starting from the bulk density of the reactant gas.

Q9. [5 marks]

Why Thiele Modulus for a reversible reaction is more than an irreversible reaction?

Q10. [5 marks]

For a solid fluid non catalytic reaction, what are the reaction models you can predict? Explain them with their practicability.

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Mid-Autumn Semester Examination 2022-23

Date of Examination: _____ **Session: (FN/AN)** _____ **Duration: 2 hrs. Full Marks: 30**

Subject No.: CH21206 **Subject: Reaction Engineering**

Department/Center/School: Chemical Engineering

Specific charts, graph paper, log book etc., required No

Special Instructions (if any): **Answer the questions writing in which Part those belong**

PART-A

Q1. **[2+2+2+3 = 9]**

The reversible isomerization $m - Xylene \rightleftharpoons$ para – Xylene follows elementary rate law kinetics. If Xe is the equilibrium conversion,

(a) Show for a batch and a PFR: $t = \tau = \frac{Xe}{k} ln \frac{Xe}{Xe-X}$

(b) Show for a CSTR: $\tau = \frac{Xe}{k}\left(\frac{Xe}{Xe-X}\right)$

(c) Determine the volume efficiency, defined as $\frac{VPFR}{VCSTR}$, for $X/Xe = 0.5$

(d) For the same $X/Xe = 0.5$, what would be the volume efficiency for two CSTRs in series with the sum of the two CSTR volumes being the same as the PFR volume?

Q2. **[6]**

The liquid-phase reaction A → B was carried out in a CSTR. For an entering concentration of 2 mol/dm^3, the conversion was 40%. For the same reactor volume and entering conditions as the CSTR, the expected PFR conversion is 48.6%. However, the PFR conversion was, amazingly, 50% exactly. Brainstorm reasons for the disparity. Quantitatively show how these conversions came about (i.e., the expected conversion and the actual conversion).

PART B

Q3. a) Write different steps associated with a gas phase solid catalytic reaction to form product.

The reaction is: A → B. **[3.5]**

b) What do you mean by active sites in a solid catalyst? How do you express its concentration? **[1+1=2]**

c) From the following rate equation, state the reaction, adsorption mechanism and reaction kinetics with logic. **[1+2+2=5]**

$$-r'_N = \frac{kP_N}{(1 + K_1P_N + K_2P_C)^2}$$

d) Derive this rate law, considering a suitable rate limiting step consistent with the given rate expression as in the question c). Keep all notations same and name the notations. **[4.5]**