Ref. No.: Ex/Che/PC/B/T/326/2023(S)

B.E. CHEMICAL ENGINEERING THIRD YEAR SECOND SEMESTER SUPPLEMENTARY EXAM 2023

CHEMICAL REACTION ENGINEERING- II

Part - I

(Marks: 50)

Answer separate Answer scripts for Part-I and Part-II

Answer from all COs

[COs have been defined at the end of the question]

CO 1

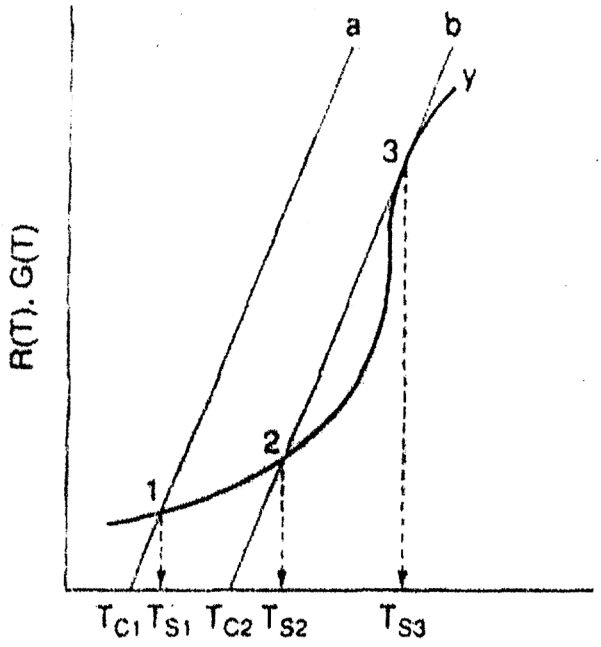
[Marks:5]

1. a) In case of series type deactivation, $-\frac{da}{dt} =$? (1)

1.b) Under strong control of internal pore diffusion, if the observed activation energy is 30kJ/mol, the actual activation energy is _____. (1)

1.c) In case of competitive inhibition the value of Michaelis Menten constant_____. (1)

1.d) What is the significance of this plot? (1)



[Turn over

1.e) For shrinking spherical particles the time for complete conversion is proportional to _____. (1)

CO2

[Marks:15]

Answer Question 2 or 3

2.a) Develop the kinetic rate equation for non-competitively inhibited enzymatic reaction. (5)

2.b) Correlate the concentration of the reactant of a first order heterogeneous catalytic reaction,

A ⟶ B with the radial position in a spherical catalyst. Derive the expression for effectiveness factor for internal mass transfer resistance controlled system. (10)

3.a) Describe the procedure by which you will determine the reaction kinetics of a first order reaction in presence of independent deactivation using a reactor with batch solid-mixed fluid modes of operation. (5)

3.b)

At room temperature sucrose is hydrolyzed by the enzyme sucrase as follows:

$$\text{sucrose} \xrightarrow{\text{sucrase}} \text{products}$$

Starting with sucrose ($C_{A0} = 1$ mol/m³) and sucrase ($C_{E0} = 0.01$ mol/m³) the following data are obtained in a batch reactor (concentrations are calculated from optical rotation measurements)

C_A, mol/m³	0.68	0.16	0.006
t, hr	2	6	10

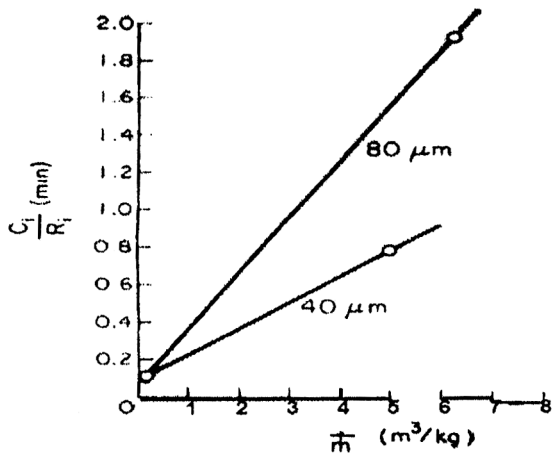
Find a rate equation to represent the kinetics of this reaction.

(10)

CO3

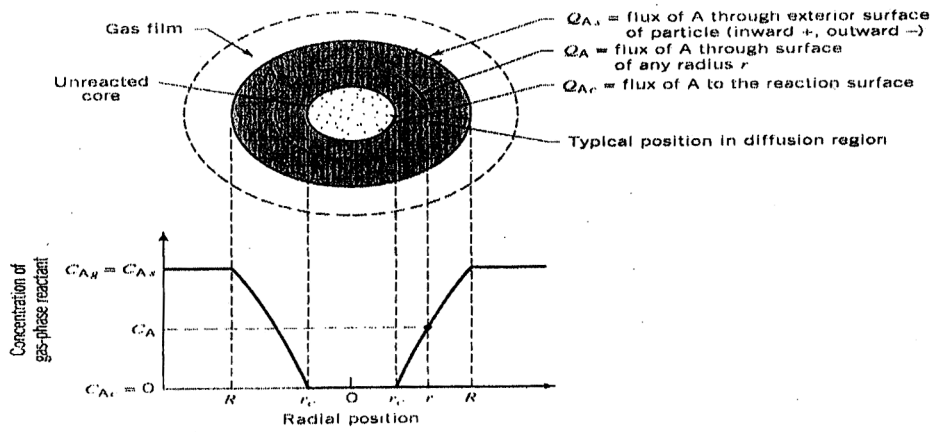
[Marks:5]

4.a) The $\frac{C_i}{r_i}$ versus $\frac{1}{m}$ plot for a slurry reactor is shown in the following figure. Which is the limiting step? (1)



4. b) Methyl linoleate is to be hydrogenated to methyl oleate in a $4m^3$ slurry reactor. From lab scale experiment it has already been established that the system is internal mass transfer controlled. The values of resistance to gas absorption, r_b and the combined resistance, r_{cr} to transport to surface of catalyst and diffusion and reaction in the catalyst pellet for 60μm catalyst are 0.08 min and 0.21 min-kg/m3 respectively. Determine the value of r_{cr} for 80mm catalyst pellets. Justify your answer. (3)

4.c) Which resistance is controlling? **(1)**



CO4

[Marks:15]

Answer Question 5 or 6

5. a) To avoid wash-out condition in a continuous stirred tank bioreactor undergoing microbial reaction, the value of dilution rate should be kept below _____. Derive. (5)

5. b) A reaction $4A(g) + B(l) \rightarrow cC(g) + dD(l)$is occurring in a trickle bed catalytic reactor. Both axial and radial dispersions are negligible in gas and liquid phases. The condition is such that the reaction is pseudo first order with respect to the concentration of A. If the liquid phase is saturated with A, correlate the conversion of B

and the length of the reactor assuming the constancy of gas phase concentration of A. (10)

6.The following non-catalytic heterogeneous reaction is occurring in an up-flow reactor:

$2NaCl + H_2O + SO_3 \rightarrow Na_2SO_4 + 2HCl$

In a laboratory test, 85% conversion of 88-105μm particle has been observed to take 10 s. Solid hold-up is 0.01. Chemical reaction is controlling. The RTD data and size analysis data are as follows:

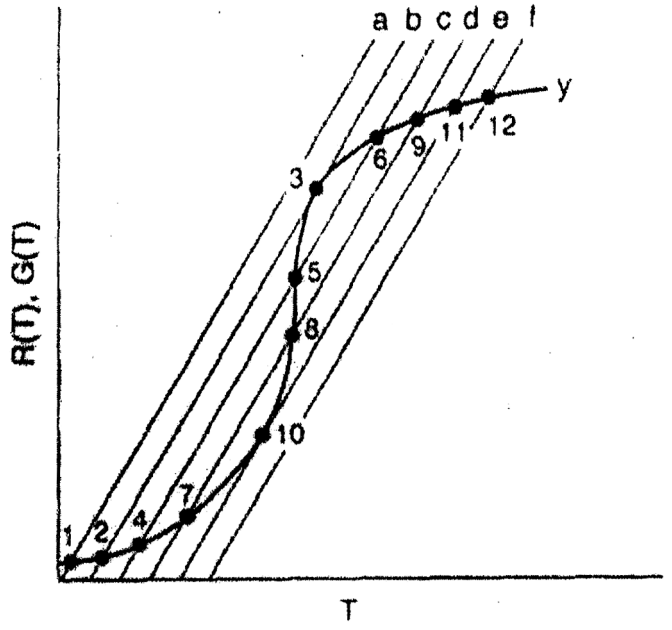
Particle size (μm)	Weight fraction	Residence time t/τ
50-60	0.4	0.6
70-80	0.4	0.9
105-125	0.2	1.3

Determine the average conversion of NaCl to Na_2SO_4. Will there be any change in the conversion if a down-flow reactor is used? Justify your answer. Data: Solid feed rate: 450 kg/min; D=0.6m; H=9.1m and ρ_b= 2100 kg/m^3. Show all derivations, wherever necessary. (15)

CO5

[Marks:10]

7. Defining steady state multiplicity, draw the ignition –extinction diagram using the following plot. How can you modulate the inlet temperature to avoid runaway condition?



Course Outcomes

CO1 **Define** and **describe** the basic mechanisms of non-catalytic and catalytic heterogeneous reactions and biochemical reactions **K1 and K2**

CO2 **Develop** rate equations for different types of heterogeneous reactions and biochemical reactions **K3**

CO3 **Determine** the controlling steps for heterogeneous reactions **K4**

CO4 **Formulate** design equations for heterogeneous reactors and bioreactors and **predict** their performance **K5& K6**

CO 5 **Explain** steady state multiplicity in CSTRs **K6**

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B. E. Chemical Engg. 3rd Year 2nd Semester Supplementary Examination, 2023
Chemical Reaction Engineering II
Part II

Use separate answer-scripts for each part

Assume any missing data

All the symbols have their usual meaning

CO1 Marks: 3

1. Give the industrial importance of Gas-Solid non-catalytic reactions. **3**

CO2 Marks: 15

2. Using the shrinking core model for spherical particles of unchanging size, develop relations between time, conversion and particle size when diffusion through gas-film controls the overall reaction rate along with a proper sketch. **15**

CO3 Marks: 5

3. Spherical particles of an ore are roasted isothermally in a constant environment in air stream. The following data is obtained: **5**

D_p, mm	X_B	t, s
2	0.875	1
1	1	1

Assume that the reaction follows the Shrinking Core Model. Find the rate controlling mechanism

CO4 Marks: 22
Answer any two

4. 1 m^3/h of a gas containing (C_{A0} = 2 mol/m^3) is fed to a plug flow reactor packed with catalyst with very large recycle is having the composition of exit stream from the reactor system of 0.5 mol A/m^3. Find the rate of equation for the decomposition of A for $A \longrightarrow 3R$, reaction order = 2, catalyst used = 3 kg and feed contains 50% A and 50% inerts. **11**

5. Determine the amount of catalyst needed in a mixed flow reactor to achieve 35% conversion of 2000 mol/h of pure gaseous reactant (A) at 3.2 atm and 117oC if the stoichiometry and rate is given by **11**

$A \longrightarrow 4R$

$-r_A` = k \times C_A$ mol/kg cat.h, k = 96.55 l/ kg cat. h.

6. A substrate (A) is hydrolyzed by an enzyme (E) as $A \xrightarrow{E} R$ with $C_{A0} = 1$ mol/m^3 and enzyme concentration, $C_{E0} = 0.01$ mol/m^3. The following data was obtained in a batch reactor.	**11**

t, hour	2	6	10
C_A, mol/m^3	0.68	0.16	0.006

Find the equation for this hydrolysis reaction.

CO5 Marks: 5	
7. What do mean by multiple steady states in CSTR and why they occur in CSTR.	**5**