U.S.N.										

B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

June 2025 Semester End Main Examinations

Programme: B.E. **Semester: V**
Branch: BIOTECHNOLOGY **Duration: 3 hrs.**
Course Code: 23BT5PCREN / 22BT5PCREN **Max Marks: 100**
Course: Reaction Engineering

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

		UNIT - I	CO	PO	Marks
1	a)	A reaction of the form A → B is monitored by the formation of product. The following concentrations of reactants as a function of time were measured: Time (t), min: 0, 10, 20, 30, 40 Concentration (C), g/m^3: 0.860, 0.740, 0.635, 0.546, 0.405 Show that the reaction is first order, calculate the rate constant, k and the half-life, $t_{½}$.	*CO2*	*PO1*	**10**
	b)	Describe temperature dependency of rate constant from transition state theory.	*CO2*	*PO1*	**10**
		OR			
2	a)	Determine the overall order of the following irreversible reaction $2A + 2B \rightarrow C + 2D$ From the following constant-volume data obtained by using equimolar quantities of reactants A and B. Take T = 296K Half-life (seconds): 265, 186, 115, 104, 67 Total pressure (mmHg): 200, 240, 280, 320, 360	*CO 3*	*2*	**10**
	b)	The rate of reaction at 40°C is three times the rate at 20°C. Determine the activation energy.	*CO2*	*PO1*	**06**
	c)	Distinguish between integral method and differential method of analysis.	*CO2*	*PO1*	**04**

Table for Q1 a):

Time (t), min	0	10	20	30	40
Concentration (C), g/m^3	0.860	0.740	0.635	0.546	0.405

Table for Q2 a):

Half-life (seconds)	265	186	115	104	67
Total pressure (mmHg)	200	240	280	320	360

<table>
<tr><td></td><td></td><td></td><td>UNIT - II</td><td></td><td></td><td></td></tr>
<tr><td></td><td>3</td><td>a)</td><td>Derive the design equation for ideal plug flow reactor for constant volume systems with suitable diagram. State the conditions.</td><td>CO2</td><td>PO1</td><td>10</td></tr>
<tr><td></td><td></td><td>b)</td><td>A specific enzyme E acts as a catalyst in the fermentation of substrate A. At a given enzyme concentration in the aqueous feed stream of 25 L/min. Estimate and compare the volume of plug flow reactor and mixed flow reactor required to achieve 95% conversion of reactant A with initial concentration $C_{A0} = 2$ mol/L. The kinetics and stoichiometry of the fermentation reaction are given by $A \rightarrow R$, $-r_A = 0.1\ C_A / (1 + 0.5\ C_A)$</td><td>CO 3</td><td>PO 2</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td></td><td></td><td></td></tr>
<tr><td></td><td>4</td><td>a)</td><td>It is planned to operate a batch reactor for converting A into R. This is a liquid phase reaction with stoichiometry $A \rightarrow R$. How long it must react in each batch for concentration to drop from $C_{Ao} = 1.3$ mol/L to $C_{Af} = 0.3$ mol/L? The data of rate of reaction v/s concentration of A is given below:
<table>
<tr><td>C_A , mol/L</td><td>0.1</td><td>0.2</td><td>0.3</td><td>1.0</td><td>1.3</td><td>2</td></tr>
<tr><td>$-r_A$, mol/L min</td><td>0.1</td><td>0.3</td><td>0.5</td><td>0.05</td><td>0.045</td><td>0.042</td></tr>
</table></td><td>CO 3</td><td>PO 2</td><td>10</td></tr>
<tr><td></td><td></td><td>b)</td><td>Derive performance equation for recycle reactor for variable volume system.</td><td>CO2</td><td>PO1</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td>UNIT - III</td><td></td><td></td><td></td></tr>
<tr><td></td><td>5</td><td>a)</td><td>The effluent concentration is measured as a function of time for a pulse input into a closed vessel. The results are tabulated below:
<table>
<tr><td>Time(t), min</td><td>0</td><td>5</td><td>10</td><td>15</td><td>20</td><td>25</td><td>30</td><td>35</td></tr>
<tr><td>Concentration (C) , g/L</td><td>0</td><td>3</td><td>5</td><td>5</td><td>4</td><td>2</td><td>1</td><td>0</td></tr>
</table>
This vessel is to be used as a reactor for the decomposition of liquid reactant. The stoichiometry of decomposition is $A \rightarrow$ products. The decomposition is first order with $k = 0.307\ min^{-1}$. Estimate the fraction of reactant unconverted in the real reactor and compare this with fraction unconverted in a plug flow reactor of same size.</td><td>CO 3</td><td>PO 2</td><td>10</td></tr>
<tr><td></td><td></td><td>b)</td><td>Explicate the significance of Tanks-in-series model. Derive design equation using Tanks-in-series model.</td><td>CO2</td><td>PO1</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td></td><td></td><td></td></tr>
<tr><td></td><td>6</td><td>a)</td><td>Prove that the conversion is same for macrofluid and microfluid for a first order reaction in a plug flow and mixed flow reactors.</td><td>CO2</td><td>PO1</td><td>10</td></tr>
<tr><td></td><td></td><td>b)</td><td>A first order liquid phase reaction is carried out in a tubular reactor. The results of a pulse tracer test on this reactor are tabulated below:</td><td>CO 3</td><td>PO 2</td><td>10</td></tr>
</table>

Time (minutes)	Concentration (μmol/dm^3)
0	0
1	1
2	5
3	8
4	10
5	8
6	6
7	4
8	3
9	2.2
10	1.5
12	0.6
14	0

Evaluate and compare the conversion of this reaction using:

(i) ideal plug flow reactor (ii) ideal mixed flow reactor and (iii) Tanks-in-series model. Take the reaction rate constant = 0.25 min^{-1}

UNIT - IV

Q.No		Question	CO	PO	Marks
7	a)	Elaborate on the different stages in microbial growth phase with suitable kinetic equations and diagram. Distinguish between different types of microbial products.	*CO2*	*PO1*	**10**
	b)	The specific growth rate for inhibited growth in a chemostat is given by the following equation: $\mu_g = \mu_m S / [K_s + S + I(K_s/K_I)]$ where, S_o = 10 g/L, X_o = 0, K_I = 0.01 g/L, K_s = 1 g/L, I = 0.05 g/L, μ_m = 0.5 h^{-1} , $Y^M_{X/S}$ = 0.1 g/g and k_d = 0 i) Find X and S as a function of D when I =0 ii) With Inhibitor added to a chemostat, determine the effluent substrate concentration and X as a function of D. iii) Determine the cell productivity as a function of dilution rate.	*CO3*	*PO2*	**10**

OR

8 a) The following data are obtained in oxidation of pesticides present in wastewater by a mixed culture of microorganisms in a continuously operating aeration tank. *CO3* *PO2* **10**

D (h^{-1})	S (pesticides), mg/L	X(cell concentration) mg/L
0.05	15	162
0.11	25	210
0.24	50	250
0.39	100	235
0.52	140	220
0.7	180	205
0.82	240	170

Assuming the pesticide concentration in the feed waste water stream as S_o = 500 mg/l, determine $Y^M_{X/S}$, k_d, μ_m and K_s.

		b)	Compare and contrast the different types of unstructured non-segregated microbial growth models with the help of kinetic equations.	*CO2*	*PO1*	**05**
		c)	Derive equation for substrate in terms of dilution rate in absence of endogenous metabolism and steady state conditions.	*CO2*	*PO1*	**05**
			UNIT - V			
	9	a)	Consider the scale-up of a fermentation from 10 liters to 10,000 liters vessel. The small fermenter has a height-to-diameter ratio of 3. The impeller diameter is 30% of the tank diameter. Agitator speed is 500rpm and three Rushton impellers are used. Determine the dimensions of the large fermenter and agitator speed for: (i) Constant P/V (ii) Constant impeller tip speed (iii)Constant Reynolds number Assume geometric similarity.	*CO 3*	*PO 2*	**8**
		b)	Describe the construction and working of air-lift reactors with suitable diagram.	*CO2*	*PO1*	**7**
		c)	Mention any five criteria for selection of bioreactors with respect to physico-chemical properties.	*CO 1*		**5**
			OR			
	10	a)	Explain the scale-up criteria for stirred tank bioreactors.	*CO2*	*PO1*	**6**
		b)	Describe the construction and working of fluidized bed reactors with suitable diagram.	*CO2*	*PO1*	**7**
		c)	After a batch fermentation, the system is dismantled and approximately 75% of the cell mass is suspended in the liquid phase with volume 2 liters, while 25% is attached to the reactor walls and internals in a thick film. Work with radioactive tracers shows that 50% of the target intracellular product is associated with each cell fraction. The productivity of this reactor is 2 g/l at the 2 liters scale. Estimate the productivity at 20000 liters scale if both reactors had a height to diameter ratio of 2 to 1?	*CO 3*	*PO 2*	**7**

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