BIOREACTOR DESIGN AND ANALYSIS
(BIOT 3202)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

SYMBOLS ARE OF USUAL SIGNIFICANCE

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) If the reaction rate doubles as the concentration of the reactant A increases by a factor of two, what is the order of the reaction with respect to A?
(a) First order (b) Zero order
(c) Pseudo first order (d) None of these.

(ii) A 5 liter chemostat is fed fresh medium at 0.2 litres / minute having a substrate concentration of 25 grams/liter. At steady state, the outgoing stream has substrate concentration of 2.5 grams / liter. The rate of consumption (grams/(liter.minute)) of the substrate in the reactor is ___.
(a) 0.86 (b) 0.53 (c) 1.2 (d) None of these

(iii) The units of 2^{nd} order rate constant is
(a) mole/lit. sec (b) mole/sec (c) lit/mole. Sec (d) 1/mole.

(iv) Immobilized cell reactors for wastewater treatment have the advantage of having / being
(a) higher cell concentration
(b) more stable prevents washout
(c) higher dilution rate before the cell washout
(d) all of the above.

(v) The kinetics of monoclonal antibodies are described by the kinetics of the type
(a) growth associated (b) non-growth associated
(c) Monod model (d) combination of (a) and (b).

(vi) If one starts with ($2x10^4$) cells in a culture that has a generation time of two hours how many cells will be in the culture after 4 hrs.
(a) $4x10^4$ cells (b) $5x10^4$ cells (c) $6x10^4$ cells (d) $8x10^4$ cells.

(vii) A non-ideal reactor is characterized by
(a) Peclet number (b) Dispersion number
(c) Reynold's number (d) Residence time distribution.

(viii) A bubble column used for aerobic fermentation is best modelled by
(a) plug flow (b) stirred tank
(c) dispersion model (d) plug flow with axial dispersion.

(ix) The approximate doubling time of a microbial culture where specific growth rate is 0.35/hr. is
(a) 1 hour (b) 2 hour (c) 3 hour (d) 6 hour.

(x) The best method to control bioreactor system is
(a) PI control system (b) PD control system
(c) PID control system (d) Proportional control system.

Fill in the blanks with the correct word

(xi) A+B → products, if C_{B0} is much larger than C_{A0}, C_B remains approximately constant at all time.
The order of the reaction will be _____.

(xii) For nth. order reaction if n < 1
The reaction will complete in _____ time

(xiii) In non-ideal reactors the parameter D, which we call the longitudinal or axial dispersion coefficient, uniquely characterizes the degree of _____ during flow.

(xiv) $-r_A = (K_1 C_A) / (1 + K_2 C_A)$ From this rate equation
At high C_A the reaction is of _____ order.

(xv) Michaelis--Menten Kinetics, $-r_A = (K C_{E0} C_A) / (C_M + C_A)$
At low C_A rate is of _____ order with respect of C_A.

Group - B

2. Lethal agents are added to a stirred tank to kill organisms in a medium. Dissolved oxygen concentration upon addition of lethal agent is recorded and following data obtained.

t (min)	1	2	2.5	3	4	5
DO (gm/m_3)	1	3	4	5	6.5	7.2

If saturation oxygen concentration is 9 gm/m^3, Calculate K_La. *[(CO3)(Analyse/HOCQ)]*

12

3. (a) Describe the method of K_La determination by dynamic method. *[(CO2)(Remember/IOCQ)]*
(b) A 20 litre stirred fermenter containing B. thuringenesis at 30°C is used for production of microbial insecticide. K_La is detrmined by using dynamic method. When steady state is established, the DO tension is 78% air saturation. Based on the experiment, the following data was obtained.

Time(sec)	5	15
Oxygen saturation (%)	50	66

(i) Estimate K_La.
(ii) An error is made in determining the steady state oxygen level which instead of 78%, is taken as 70%. What is the percentage error in Kla resulting from 8% error in oxygen saturation? *[(CO2)(Evaluate/IOCQ)]*

6 + (3 + 3) = 12

Group - C

4. (a) The first-order reversible reaction $A \rightarrow R$, $C_{A0} = 0.5$ moles/lit. $C_{R0} = 0$ takes place in a batch reactor. After 8 minutes, conversion of A is 33.3% while equilibrium conversion is 66.75%. Find the rate equation for this reaction. *[(CO1)(Analyse/HOCQ)]*

(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, the volume of the reaction mixture, starting with 80 % A, decreases by 20% in three minutes.

[(CO1)(Calculate/LOCQ)]

8 + 4 = 12

5. A small reaction bomb fitted with a sensitive pressure-measuring device is flushed out and then filled with pure reactant A at 1-atm pressure. The operation is carried out at 27 ^{0}C, a temperature low enough that the reaction does not proceed to any appreciable extent. The temperature is then raised as rapidly as possible to 100 ^{0}C by plunging the bomb into boiling water and the reading is given below (time vs pressure). Generate time (t) vs C_A data and then suggest a suitable rate equation which will satisfactorily fit the data.

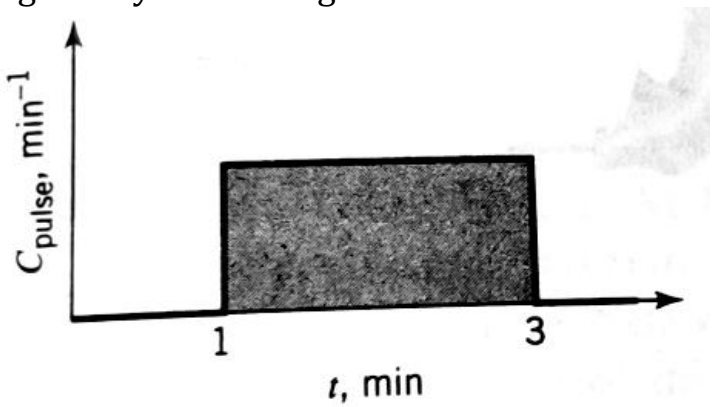
t (min)	1	2	3	4	5	6	7	8	9	10	15	20
P (atm)	1.14	1.04	0.98	0.94	0.90	0.87	0.85	0.83	0.81	0.80	0.75	0.72

[(CO3)(Analyse/HOCQ)]

(6 + 6) = 12

Group - D

6. (a) Dispersed non-coalescing droplets (C_{A0} =2 mol/lit) react ($A \rightarrow R$, $-r_A = K C_A^2$, K = 0.5 lit./mol. min) as they pass through a contactor. Find the average concentration of 'A' remaining in the droplet leaving the contactor if their R T D is given by the curve given below. *[(CO5)(Analyse/IOCQ)]*



(b) A specific enzyme acts as catalyst in the fermentation of reactant 'A'. At a given enzyme concentration in the aqueous feed stream (25 lit. / min) find the volume of the P F R needed for 95 % conversion of reactant 'A' (C_{A0} = 2 mol/lit.). The kinetics of the fermentation at this enzyme concentration is given below.

$A \rightarrow R$, $-r_A = (0.1 C_A) / (1 + 0.5 C_A)$ mole / lit. min. *[(CO4)(Remember/LOCQ)]*

6 + 6 = 12

7. (a) The concentration reading given below represent a continuous response to a pulse input into a closed vessel

t (min)	0	5	10	15	20	25	30	35
C_{pulse}, gm/lit	0	3	5	5	4	2	1	0.001

This vessel is to be used as a reactor for the decomposition of a liquid reactant 'A'. A → Products. $-r_A = K C_A$, $K = 0.307\ min^{-1}$.

Estimate the fraction of the reactant unconverted in the real reactor and compare this with the fraction unconverted in a PFR of same size.

[(CO5)(Analyse/HOCQ)]

(b) Explain significance of dispersion number. *[(CO5)(Remember/LOCQ)]*

10 + 2 = 12

Group - E

8. (a) A culture of E. coli was grown on lactose in a mixed flow reactor (V = 1 liter) using various flow rates of a C_{A0} = 160 mg lactose/lit feed. The following results were obtained:

V, liter/hr	C_A, mg/liter	Cell concentration
0.2	4	15.6
0.4	10	15.0
0.8	40	12.0
1.0	100	6.0

Find a rate equation to represent this growth. *[(CO6)(Analyse/HOCQ)]*

(b) Define enzyme. *[(CO1)(Remember/LOCQ)]*

10 + 2 = 12

9. (a) A -→ Product.

Derive nth. Order rate equation. The equation is valid for any value of 'n'?

If you assume (n > 1) how much time it will take to complete the reaction.

[(CO2)(Remember/LOCQ)]

(b) Derive zero-order rate equation and show the result graphically in terms of C_A and X_A. *[(CO3)(Remember/LOCQ)]*

(c) Derive first order rate equation from Michaelis-Menten rate equation.

$-r_A = (K_3 C_A C_{E0}) / (C_A + C_M)$

A kinetic equation of the Michaelis - Menten type. *[(CO3)(Remember/IOCQ)]*

(2 + 1 + 2) + (2 + 2) + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	19.79	26.04	54.17

Course Outcome (CO):

After completing the course, the students will be able to:

1. Develop basic concept of reaction engineering.
2. Understand basic concepts of bioreactor design and analysis.
3. Understand the basic operating principles of bioreactors.
4. Interpret batch reactor data with reference to basic reactor design for a single reaction ideal reactor.
5. Analyze non-ideal flow pattern with reference to residence time distribution (RTD) and dispersion numbers (D/UL).
6. Analyze basic cell growth data to verify Monod model.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*