Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(BT)/SEM-5/BT-502/2011-12

2011

BIOREACTOR DESIGN AND ANALYSIS

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

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

GROUP – A
(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following :

$10 \times 1 = 10$

i) Sherwood Number is given by the expression

a) $K_L d_f / D_{AB}$ b) $K_L d_b / D_{AB}$

c) $K_L L_C / D$ d) $K_L \rho / D_{AB}$.

ii) If the rate is given as $-r_A = k\, C_A^{0.6} C_B^{0.4}$ then the molecularity and order of the reaction is

a) 1 and 1 b) 1 and 2

c) 2 and 1 d) 2 and 2.

iii) A chemostat can be operated at dilution rate which is

a) higher than the specific growth rate

b) lower than the specific growth rate

c) equal to the specific growth rate

d) not related to the specific growth rate.

iv) A non-ideal reactor is characterized by

a) residence time distribution

b) Peclet number

c) combination of reactor

d) segregated model.

v) For enzymatic reactions, at low substrate concentration, rate is

a) 1st order with respect to substrate concentration

b) zero order with respect to substrate concentration

c) fractional order with respect to substrate concentration

d) none of these.

vi) If effectiveness factor is less than 1, the conversion in immobilized enzymatic reaction is

a) reaction rate limiting

b) oxygen concentration limiting

c) diffusion limiting

d) shear rate limiting.

vii) Animal cell culture is best carried out in

a) batch culture

b) stirred tank reactor

c) bubble column reactor

d) air-lift fermentor.

viii) Monod model is an equation of which of the following types ?

a) Linear b) Nonlinear

c) Hyperbolic d) Parabolic.

ix) 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.

x) Trickle bed reactor is characterized by

a) high L/D ratio

b) high flow rate of the liquid

c) counter current flow of gas and liquid stream

d) mass transfer.

xi) Change in impeller tip speed depends on

a) shear rate b) viscosity

c) density d) surface tension.

xii) In inhibitory enzyme kinetics, the inhibitor is substrate analogue in

a) allosteric enzymatic reaction

b) competitive inhibition

c) uncompetitive inhibition

d) non-competitive inhibition.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Liquid *A* decomposes by second order kinetics and in a batch reactor 50% of *A* is converted in a 5 minute run. How much longer would it take to reach 75% conversion ?

3. A plug flow reactor (2 m^3) processes an aqueous feed (100 litre/min) containing reactant *A* (C_{A0} = 100 mmol/litre). This reaction is reversible and represented by

   $A \rightleftharpoons R,\ -r_A = 0 \cdot 04\,(\text{min}^{-1})\,C_A - 0 \cdot 01\,(\text{min}^{-1})\,C_R$

   What is the equilibrium conversion and the actual conversion in the reactor ?

4. Write short notes on trickle bed reactor & membrane reactor.

5. Describe the method of determining $K_L a$ by the steady state method where the oxygen uptake rate is $q_{o_2} x$.

6. The optimum agitation speed for the cultivation at plant cells in a 3L fermenter equipped with four leafless was found to be 150 rpm. The length and diameter ratio at the fermenter is 3. What should be the (a) dimensions of a geometrically similar 1 m^3 fermenter and (b) the impeller speed based on the same power consumption per unit volume ? Given, impeller diameter $D_I = 0 \cdot 3D$, where *D* is the diameter (internal) of the reactor.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Write short note on Hollow fiber reactor for the production of monoclonal antibodies.

   b) How does dispersion no. link with the degree of mixing in a bioreactor ?

   c) What is the significance of tanks-in-series model to explain the behaviour of non-ideal reactors ? How does the parameter N affect the E-curve generated by pulse input to the flowing stream in a vessel ? 5 + 3 + 7

8. a) What are the characteristic features of a bubble column bioreactor used for aerobic fermentation ? How does the liquid phase mass transfer coefficient affect the performance of a reactor ?

   b) A high molecular weight hydrocarbon gas is fed continuously to a heated mixed flow reactor where it cracks as follows : $A \rightarrow 5R$.

   By changing the feed rate, different extent of cracking are obtained as follows :

F_{A_0}, mol/hr	0·3	1·0	3·0	5·0
$C_{A_{out}}$, mol/m^3	0·016	0·030	0·050	0·06

7 + 8

9. a) A specific microorganism is used for a chemostat culture of 60 m^3 fermenter to produce alcohol from glucose. The feed contains 12 kg/m^3 glucose. The kinetic parameters of the system are : $K_s = 0 \cdot 2$ kg/m^3, $\mu_{max} = 0 \cdot 3\ hr^{-1}$, $Y_{X/S} = 0 \cdot 06$, $Y_{P/X} = 7 \cdot 7$ and q_p(specific product formation rate) = $3 \cdot 4\ hr^{-1}$.

Calculate the flow rate which is required for an outlet substrate concentration $s = 1 \cdot 5$ kg/m^3.

b) In a number of separate runs different concentrations of substrate and enzyme are introduced into a batch reactor and allowed to react. After a certain time the reaction is quenched and the vessel contents analyzed. From the results found below find a rate equation to represent the action of enzyme on substrate.

Run	C_{E0} (mol/m^3)	C_{A0} (mol/m^3)	C_A (mol/m^3)	t (hr)
1	3	400	10	1
2	2	200	5	1
3	1	20	1	1

7 + 8

10. a) What are the differences between plant cells & microbes & implication for bioreactor design ?

b) The rule of thumb that the rate of reaction doubles for a 10°C increase in temperature occurs only at specific temperature for a given activation energy (*i.e.* for specific combination of temperature and activation energy). Show that the relationship between activation energy and temperature for which the rule holds is $T = [10(K).E/R.\ln^2]^{\frac{1}{2}}$.

c) Write short note on Fluidized Bed Reactor. 5 + 5 + 5

11. a) A stream of pure gaseous reactant *A* (C_{AO} m mol/L) enters a plug flow reactor at a flow rate of F_{AO} = 540 m mol/min and polymerizes there as follows :

$3B \rightarrow R, -r_A$ = 54 m mole/(litre)(min)

How large a reactor is needed to lower the concentration of *A* in the exit stream to C_{Af} = 330 m mol/L ?

b) Enzyme *E* catalyses the fermentation of substrate *A* (the reactant) to product *R*. Find the size of mixed flow reactor needed for 95% conversion of reactant in a feed stream (25 litre/min) of reactant (2 mol/litre) and enzyme. The kinetics of the fermentation at this enzyme concentration are given by

$$A \xrightarrow{\text{enzyme}} R\ ,\ -r_A = \frac{0 \cdot 1 C_A}{1 + 0 \cdot 5 C_A} \text{ mol/litre. min} \qquad 8 + 7$$

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