Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech(BT)/SEM-5/BT-502/2009-10

2009

BIOREACTOR DESIGN & 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) The molecularity of any reaction will be

a) integral number b) fractional number

c) both (a) & (b) d) constant.

ii) The order of any reaction will be

a) integral number b) fractional number

c) both (a) & (b) d) constant.

iii) Which of the following is the steady state reactor ?

a) Batch reactor b) CSTR

c) Plug flow reactor d) Both (b) & (c).

iv) The unit of 2nd order reaction constant when partial pressure will be used in place of concentration is

a) atm^{-2} b) $time^{-1}\ atm^{-2}$

c) $time^{-1}\ atm^{-1}$ d) atm^{-1} .

v) Animal cell culture is best carried out in which type of reactor ?

a) Batch reactor

b) Stirred tank reactor

c) Air-lift fermenter

d) Bubble column reactor.

vi) 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) $K_L\ \rho\ /D_{AB}$

vii) A non-ideal reactor is characterized by

a) Residence time distribution

b) Peclet number

c) Combination of reactor

d) Segregated model.

viii) Air-lift fermenter is used for production of

a) alcohol b) penicillin *G*

c) enzymes d) mabs.

ix) Perfusion reactor is used for

a) Vaccine formation

b) Animal cell culture

c) Alcohol production

d) Biomass production.

x) Monod model for cell mass growth is a/an

a) Mechanistic model

b) Deterministic model

c) Unstructured model

d) Structured model.

xi) Microbial fermentation is best carried out for high yield of cell mass by

a) Plug flow reactor

b) Fed batch reactor

c) Back-mixed reactor

d) Fluidized bed reactor.

xii) Maximum growth of *E.coli* is obtained by which of the following combinations of reactors ?

a) two plug flow reactors in series

b) two CSTRs in series

c) a CSTR followed by plug flow reactor

d) plug flow reactor followed by a CSTR.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. The pyrolysis of ethane proceeds with an activation energy of 300 kJ/mol. How much fast is the decomposition at 65°C than at 500°C ?

3. For the elementary reaction in series :

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C,\ k_1 = k_2,\ \text{at } t = 0 \begin{cases} C_A = C_{A_0} \\ C_{B_0} = C_{S_0} = 0 \end{cases}$$

Find the maximum concentration of *B*. When is it reached ?

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

5. After 8 minutes in a batch reactor, reactant *A* (C_{A_0} = 1 mol./lt.) is 80% converted; after 18 minutes conversion is 90%. Find a rate equation to represent this reaction.

6. Consider the scale up of a fermenter from a 10 lt. to 10,000 lt. vessel. The small fermenter has a height to diameter ratio of 3. The impeller diameter is 30% of the tank diameter. Agitator speed is 500 rpm. Determine the dimension of large fermenter (D_t, D_i & H) by using geometric similarity.

GROUP – C

(Long Answer Type Questions)

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

7. a) Find the overall order of the irreversible reaction

$$2H_2 + 2NO \longrightarrow N_2 + 2H_2O$$

from the following constant volume data using equimolar amounts of hydrogen & nitric oxide :

Total pressure, mm Hg	200	240	280	320	360
Half-life, sec	265	186	115	104	67

8

b) Gaseous reactant A decomposes as follows :

$A \varnothing 3R \qquad -r_A = (0{\cdot}6 \text{ min}^{-1}) C_A$

Find the conversion of *A* in a 50% *A* – 50% inert feed (v_0 = 180 lt/min, C_{A_0} = 300 mmol/lt to a $1m^3$ mixed flow reactor. 7

8. a) A value of $k_L a$ = 30 h^{-1} has been determined for a fermenter at its maximum practical agitator rotational speed and with air being sparged at 0·5 lt gas/lt reactor volume-min. *E. coli* with a q_{o_2} of 10 mmol O_2 / g-dry wt.-*h* are to be cultured. The critical dissolved oxygen concentration is 0·2 mg/lt. The solubility of oxygen from air in the fermentation broth is 7·3 mg/lt at 30°C.

i) What maximum concentration of *E. coli* can be sustained in this fermenter under aerobic conditions ?

ii) What concentration should be maintained if pure oxygen was used to sparge the reactor ? 10

b) Describe the operation of a CSTR with a perfusion system to obtain the high field of product in an animal cell culture. 5

9. a) The specific growth rate for inhibited growth in a chemostat is given by the following equation :

$$\mu_g = \mu_m \, S / (K_s + S + IK_s / K_I)$$

where,

$S_0 = 10$ g/lt $K_s = 1$ g/lt I = 0·05 g/lt $Y_{x/s}^{M} =$ 0·1 g cells/g subs

$X_0 = 0$ $K_I = 0{\cdot}01$ g/lt $\mu_m = 0{\cdot}5\ h^{-1}$ $k_d = 0$

i) Determine 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, DX, as a function of dilution rate. 10

b) Describe the method of determining $k_L a$ by the steady state method where the oxygen uptake rate (OUR) is $q_{o_2} X$. 5

10. a) How does dispersion number correlate with the degree of mixing in a bioreactor ? 2

b) A 1st order reaction is carried out in a reactor with specific reaction rate of 0·25 min^{-1} .

Following are the results of a tracer test carried out in this reactor :

Time (sec)	0	1	2	3	4	5	6	7	8	9	10	12	14
Concentration of Tracer (mg/lt)	0	1	5	8	10	8	6	4	3	2·2	1·5	0·6	0

Calculate conversion using closed vessel dispersion model. 13

11. Attempt any three of the following : $3 \times 5 = 15$

a) What are the advantages & disadvantages of a bubble column reactor for aerobic microbial fermentation ?

b) What do you know about the perfusion reactor system for animal cell culture ?

c) Describe an air-lift bioreactor with a neat diagram. What are its specific advantages over other conventional bioreactors ?

d) Derive the design equation for CSTR & PFR.