ADVANCES IN BIOREACTOR DESIGN, DEVELOPMENT AND SCALE UP
(BIOT 5202)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Symbols are of usual significance

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Perfusion reactor is used for the production of
(a) antibiotics (b) alcohol
(c) monoclonal antibodies (d) single cell protein.

(ii) The scale-up criterion for a CSTR to be used for animal cell culture is based on
(a) geometric similarity
(b) equal P/V ratio
(c) equal tip velocity
(d) equal impeller based Reynolds Number (R_{eI}).

(iii) Antibiotics are best produced in the reactor type
(a) packed bed (b) bubble column
(c) CSTR (d) Air lift.

(iv) Monoclonal antibodies are best produced in a reactor of the type
(a) CSTR without baffles (b) air-lift fermenter
(c) bubble column (d) hollow fiber reactor.

(v) Low flow rate of a gas is measured by
(a) rotameter (b) orificemeter
(c) wet gas meter (d) thermo-anemometer.

(vi) Trickel bed reactor is characterized by
(a) mass transfer (b) low L/D ratio
(c) combination (a) & (b) (d) small flow rate of liquid.

(vii) Cell suspension is a non-Newtonian fluid of the type
(a) bingham plastic (b) pseudo plastic
(c) dilatants (d) none of (a), (b) & (c).

(viii) Power number (P_{no}) varies with Re_I (impeller Reynolds number)
For turbulent flow regime
(a) P_{no} varies with Re_I inversely (b) varies directly
(c) P_{no} varies with Re_I asymptotically (d) N_{no} becomes independent of Re_I.

(ix) The design parameter of a Monod's chemostat model is
(a) residence time (b) dilution factor
(c) specific growth rate (d) space time.

(x) In case of competitive type of inhibition
(a) V_{max} is directly proportional to inhibitor concentration
(b) V_{max} is inversely proportional to inhibitor concentration
(c) V_{max} is unaffected by inhibitor concentration
(d) V_{max} is asymptotically related to inhibitor concentration.

Group - B

2. (a) A stirred tank reactor is to be scaled down from $10m^3$ to $0.1m^3$. The dimensions of the large tank are: D_t=2m, D_i= 0.5m. N=100rpm.
(i) Determine the dimensions of the small tank by using geometric similarity.
(ii) What would be the required rotational speed of the impeller in the small tank if the following criteria were used?
- Constant tip speed
- Constant impeller Re number. *[(CO3)(Analyze/IOCQ)]*

(b) *E.Coli* have a maximum respiration rate, q_{o2max}, 240mg O_2/gX.h. It is desired to achieve a cell mass of 20gX/L. The k_La is $120h^{-1}$ in a 1000L reactor. A gas stream enriched in oxygen is used which gives a value of C*= 28mg/L. If oxygen becomes limiting, growth and respiration slow; for example,
$q_{O2} = \frac{q_{o2max}\, CL}{\frac{0.2mg}{L}+CL}$, where C_L is the dissolved oxygen concentration in thefermenter.
What is C_L when the cell mass is at 20g/L? *[(CO2)(Compute/IOCQ)]*

6 + 6 =12

3. In the presence of a homogeneous catalyst of a given concentration, aqueous reactant A is converted to product at the following rates, and C_A alone determines this rate:

C_A, (mol/L)	1	2	4	6	7	9	12
$-r_A$, (mol/L.h)	0.06	0.1	0.25	1	2	1	0.5

We plan to run this reaction in a batch reactor at the same catalyst concentration as used in getting the above data. Find the time needed to lower the concentration of A from C_{A0} =10 mol/L to $C_{A\,f}$= 2 mol/L. *[(CO2)(Calculate, Analyse/IOCQ)]*

12

Group - C

4. (a) Find the first order rte constant for the decomposition of A in the gas reaction $2A \rightarrow R$ If, on holding the pressure constant, the volume of the reaction mixture, starting with 80 % A , decreases by 20% in 3 min. *[(CO4)(Remember/LOCQ)]*

(b) Enzyme E catalyzes the transformation of reactant A to product R as follows:

$$A \rightarrow R, \; -r_A = [\, 200\, C_A\, C_{E0} \,] / [\, 2 + C_A \,] \quad \text{mol/lit min}$$

If we introduce enzyme (C_{E0} = 0.001 mol/lit.) and reactant (C_{A0} = 10 mol/lit.) into a Batch reactor and let the reaction proceed, find the time needed for the concentration of reactant to drop to 0.025 mol/lit. *[(CO4)(Remember/LOCQ)]*

6 + 6 = 12

5. (a) At room temperature sucrose is hydrolysed by the catalytic action of the enzyme as Follows

Sucrose → products

Starting with a sucrose concentration C_{A0} = 1.0 mol/lit and an enzyme concentration C_{E0} = 0.01mol/lit, the following kinetic data are obtained in a batch reactor.

C_A (mol/lit.)	0.84	0.68	0.53	0.38	0.27	0.16	0.09	0.04	0.018
t(hr)	1	2	3	4	5	6	7	8	9

Determine whether these data can be reasonably fitted by the kinetic equation given below

$$-r_A = [\, K_3\, C_A\, C_{E0} \,] / [\, C_A + C_M \,]$$

If the fit is reasonable, evaluate the constant K_3 and C_M .

[(CO4)(Understand/HOCQ)]

6 + 6 = 12

Group – D

6. (a) Explain different methods of scale-up. *[(CO3)(Remember/IOCQ)]*

(b) It is desire to scale-up a batch crystallization of an antibiotic based on experiments with a One liter crystallizer. The use of a 3 cm diameter impeller at a speed of 800 rpm led to good crystallization results. For maintain power per volume constant upon scale-up to 300 liters , what should be the speed of the large-scale impeller ? The solvent has the same density and viscosity as water.

[(CO3)(Understand/HOCQ)]

4 + 8 = 12

7. (a) What are the main considerations for animal cell culture reactors ?

[(CO1)(Remember/LOCQ)]

(b) Discuss merits and demerits of immobilization both for cells and enzymes.

[(CO5)(Understand/LOCQ)]

6 + 6 = 12

Group – E

8. Write notes on –

(i) What is solid state fermentation (S S F). *[(CO5)(Remember/LOCQ)]*

(ii) Explain different types of products obtained from S S F. *[(CO5)(Understand/LOCQ)]*

(iii) Discuss different drawback of S S F. *[(CO5)(Analyse/IOCQ)]*

(4 + 4 + 4) = 12

9. (a) What do you understand by the term " Bioreactor"? *[(CO1)(Remember/LOCQ)]*
   (b) Discuss the basic instrumentation required for a fermenter (bioreactor). *[(CO6)(Understand/LOCQ)]*

2 + 10 = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*45.8*	*29.1*	*25.1*

Course Outcome (CO):

After completing this course, students should be able to:

1. Develop basic concept of reaction engineering including microbial growth kinetics.
2. Determine mass transfer coefficient.
3. Cultivate knowledge about different reactor operations and scale up and scale down.
4. Interpret batch reactor data with reference to basic reactor design for a single reaction in an ideal reactor.
5. Develop understanding about different advanced bioreactors.
6. Be familiar with the bioreactor instrumentation for monitoring and control of bioprocesses.

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