

BIOPROCESS ENGINEERING
(CHEN 3141)

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.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) In an enzymatic reaction if
(a) $C_A = K_m$, half the enzyme is in free form, the other half is combined
(b) $C_A = K_m$, most of the enzyme is tied up as complex X
(c) $C_A = K_m$ most of the enzyme is in free form
(d) none of the above.
- (ii) A plot of $(-r_A)^{-1}$ versus $(C_A)^{-1}$ is called
(a) the Eadie Hofstee plot
(b) the Lineweaver and Burk plot
(c) the Hanse Woolf plot
(d) none of the above.
- (iii) The phase of growth in which the microbial species adjusts to the new environment is known as
(a) Lag phase
(b) Death phase
(c) Stationary phase
(d) Log phase.
- (iv) A microorganism exhibits Monod growth with the following parameters: $\mu_m = 0.6 \text{ h}^{-1}$, $K_s = 4 \text{ g/l}$. The specific growth rate of the organism at a substrate concentration 2 g/l will be
(a) 0.2 h^{-1} (b) 0.3 h^{-1} (c) 0.4 h^{-1} (d) 1.2 h^{-1}
- (v) In a chemostat, which one of the following would increase the exit cell concentration?
(a) Increase in impeller size
(b) Increase in inoculum size
(c) Increase in inlet substrate concentration
(d) Increase in dilution rate.
- (vi) A support matrix for cell immobilization by entrapment is
(a) alumina
(b) sephadex
(c) glutaraldehyde
(d) calcium alginate.
- (vii) Effectiveness factor is
(a) high if Thiele modulus is low
(b) high if Thiele modulus is high
(c) independent of Thiele modulus
(d) none of the above.

- (viii) Pick the correct sentence
 (a) A chemostat with recycle can operate at dilution rates greater than specific growth rate
 (b) A chemostat can operate at dilution rates greater than specific growth rate
 (c) The cell concentration from a chemostat with recycle is lower than that obtained from a chemostat
 (d) The cell concentration factor in a chemostat with recycle is less than 1.
- (ix) Pore size range of ultrafiltration membrane is
 (a) 20-1000 Å (b) 20-1000 μm
 (c) 20-1000 mm (d) 20-1000 nm.
- (x) The chemical widely used to lyse animal cells is
 (a) ethanol (b) acetone (c) toluene (d) triton -X 100.

Fill in the blanks with the correct word

- (xi) When the substrate (A) and the substance B attack the same site on the enzyme, we have _____ inhibition
- (xii) Power number in an agitated system is expressed as _____.
- (xiii) The microorganism responsible for production of penicillin is _____.
- (xiv) The heat exchanger used in continuous sterilization process is _____.
- (xv) Molecular weight cut off of a membrane is defined as _____.

Group - B

2. (a) Derive the Michaelis-Menten equation for finding the enzymatic rate equation and show that it represents the equation of a section of rectangular hyperbola. [[CO1](Remember/LOCQ)]
- (b) What are the assumptions and drawbacks of Michaelis-Menten equation? [[CO1](Remember/LOCQ)]
- (c) Find the initial slope of Michaelis-Menten equation. [[CO1](Remember/LOCQ)]
- 6 + 3 + 3 = 12**
3. (a) Deduce the performance equation of a chemostat used for conducting a liquid phase enzyme catalyzed reaction in terms of its residence time (τ_m). [[CO2](Apply/IOCQ)]
- (b) Substrate (A) and enzyme (E) flow through a mixed flow bioreactor (Chemostat) having volume 6 litre. From the entering and leaving concentrations and flow rate, find a rate equation to representation the action of enzyme on substrate.

Data:

Initial concentration of enzyme (C_{E0}), mol /litre	Initial concentration of substrate (C_{A0}), mol /litre	Exit concentration of substrate (C_A), mol /litre	Volumetric flow rate, liter/hr.
0.01	1.0	0.1	0.3
0.01	1.5	0.5	1.0
0.01	2.5	2.0	4.0

[[CO1](Apply/IOCQ)]

5 + 7 = 12

Group - C

4. (a) “Microbial growth rate depends on nutrient concentration.” State True or False and justify. [[CO1](Analyse/IOCQ)]
- (b) Batch fermentation of an anaerobic bacterium growing on methanol gives the following results

Time h	0	2	4	8	10	12	14	16	18
X Kg/m ³	0.2	0.24	0.3	1	1.8	3.2	5.6	6.2	6.15
S Kg/m ³	9.2	9.18	9	8	6.8	4.6	0.9	0.08	0

Calculate

- (i) Maximum growth rate (ii) Yield coefficient based on substrate
 (iii) Mass doubling time (iv) Saturation constant
 (v) Specific growth rate at 16 h. [[CO1](Apply/HOCQ)]
- (c) “Exponential phase is also known as balanced growth phase” Justify. [[CO1](Analyse/IOCQ)]
- 3 + 7 + 2 = 12**

5. (a) Xanthan gum is produced using *Xanthomonas campestris* in batch culture. Laboratory experiments have shown that for each gram glucose utilised by the bacteria, 0.23 g oxygen and 0.01 g ammonia are consumed, and 0.75 g gum, 0.09 g cells, 0.27 g gaseous CO₂ and 0.13 g H₂O are formed. Medium containing glucose and ammonia dissolved in 20000 litres water is pumped into a stirred fermenter and inoculated with the microorganism. Air is sparged into the fermenter, the total amount of off-gas recovered during the entire batch culture is 1250 kg. Because of high viscosity and difficulty in handling xanthan gum solutions, the final gum concentration should not exceed 3.5 wt %.

- (i) How much glucose and ammonia are required?
 (ii) What percentage of excess air is required? [[CO3](Apply/HOCQ)]
- (b) Describe the different types of spargers with the aid of labelled diagram. [[CO3](Remember/LOCQ)]
- (c) Explain the purpose of providing aeration and agitation in a fermenter. [[CO3](Understand/LOCQ)]
- 6 + 4 + 2 = 12**

Group - D

6. (a) *Zymomonas mobilis* is used to convert glucose to ethanol in a batch fermenter under anaerobic conditions. Yield of biomass from the substrate is 0.06 g/g, $Y_{P/X}$ is 7.7 g/g, the maintenance coefficient is 2.2 g/g/h, specific rate of product formation due to maintenance is 1.1 h⁻¹. Maximum specific growth rate of *Zymomonas mobilis* is 0.3 h⁻¹. 5 g bacteria are inoculated into 50 litre medium containing 12 g/l glucose. Determine batch culture times required to

- (i) produce 20 g biomass (ii) achieve 90% substrate conversion
 (iii) produce 100 g ethanol. [[CO3](Analyse/HOCQ)]
- (b) Derive the expression of apparent yield coefficient in a chemostat in terms of true yield coefficient and maintenance coefficient. [[CO3](Apply/IOCQ)]
- (c) Explain the significance of washout point in a chemostat. [[CO3](Understand/LOCQ)]
- 6 + 4 + 2 = 12**

7. (a) A 5 m³ fermenter is operated continuously with feed substrate concentration 20 kg/m³. The microorganism cultivated in the reactor has following characteristics:
 $\mu_{\max}=0.45 \text{ h}^{-1}$, $K_s=0.8 \text{ kg/m}^3$, $Y_{x/s}=0.55 \text{ kg/kg}$
 (i) What feed flowrate is required to achieve 90% substrate conversion?
 (ii) How does the biomass productivity at 90% substrate conversion compare with the maximum possible? [[CO3)(Analyse/HOCQ]]
- (b) Derive the expression for steady state cell concentration and substrate concentration in a chemostat with recycle. [[CO3)(Apply/IOCQ]]
- (c) Discuss the working principle of bubble column bioreactors with diagram. [[CO3)(Remember/LOCQ]]
- 4 + 4 + 4 = 12**

Group - E

8. (a) "Recovery and concentration of penicillin from fermentation broth required two stage extraction". Comment on the validity of the statement. Explain the extraction process of penicillin with a diagram. [[CO4)(Analyse/IOCQ]]
- (b) Discuss the process of protein purification using aqueous two phase extraction. [[CO4)(Remember/LOCQ]]
- (3 + 3) + 6 = 12**
9. (a) Discuss the working principle of a hollow fibre membrane module with a diagram. [[CO4)(Remember/LOCQ]]
- (b) "Permeability of a membrane increases with increase in cross-flow velocity". Justify the statement. [[CO4)(Apply/IOCQ]]
- (c) "Flux increases monotonically with transmembrane pressure drop in ultrafiltration". Justify the statement with a diagram. [[CO4)(Apply/IOCQ]]
- (d) Discuss the different permeate flux models in ultrafiltration. [[CO4)(Remember/LOCQ]]
- 3 + 3 + 3 + 3 = 12**

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	37.5	38.5	24