

BIOPROCESS ENGINEERING
(CHE3231)

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) Fermentation Technology is that engineering activity concerned with the:
 - (a) Exploitation of biochemical reactions on a commercial scale
 - (b) Exploitation of biochemical reactions on laboratory scale
 - (c) Exploitation of biochemical reactions on bioreactor design only.
 - (d) None of the above
- (ii) The intercept on y-axis of the Eadie - Hofstee plot of an enzyme reaction under competitive inhibition is:
 - (a) k_3
 - (b) k_3/K_m
 - (c) K_m/k_3
 - (d) None of the above
- (iii) The yield coefficient of biomass(X) with respect to substrate(S) is defined as
 - (a) $\frac{\Delta X}{\Delta S}$
 - (b) $-\frac{\Delta X}{\Delta S}$
 - (c) $\frac{\Delta S}{\Delta X}$
 - (d) $-\frac{\Delta S}{\Delta X}$
- (iv) The end product of glycolysis is
 - (a) Pyruvic acid
 - (b) Maleic acid
 - (c) Succinic acid
 - (d) Acetic acid
- (v) Organisms requiring organic carbon source and a chemical source of energy are
 - (a) Photoautotrophs
 - (b) Chemoheterotrophs
 - (c) Photoheterotrophs
 - (d) Chemoautotrophs
- (vi) 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
- (vii) A support matrix for cell immobilization by entrapment is
 - (a) alumina
 - (b) Sephadex
 - (c) Glutaraldehyde
 - (d) calcium alginate

(viii) Pick up the correct relation

(a) $\frac{1}{Y_{X/S}^{AP}} = \frac{1}{Y_{X/S}^M} + \frac{m_s}{D}$

(b) $\frac{1}{Y_{X/S}^M} = \frac{1}{Y_{X/S}^{AP}} + \frac{m_s}{D}$

(c) $\frac{1}{Y_{X/S}^{AP}} = \frac{1}{Y_{X/S}^M} + \frac{1}{D}$

(d) $Y_{X/S}^{AP} = Y_{X/S}^M + \frac{m_s}{D}$

(ix) If C_p , C_f and C_m are the concentration of solute in permeate, feed and membrane surface respectively, observed rejection by a membrane is expressed as

(a) $1 - C_p/C_f$

(b) $1 - C_p/C_m$

(c) $1 - C_m/C_f$

(d) $1 - C_m/C_p$

(x) Pore size range of ultrafiltration membrane is

(a) 20-1000 Å

(b) 20-1000 µm

(c) 20-1000 mm

(d) 20-1000 nm

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) The production of ethanol rather than biomass from yeast cells at high concentration is known as _____ effect.

(xiii) The energy and carrier-independent mode of entry of molecules is known as _____

(xiv) The biomass concentration obtained at steady state from a chemostat in absence of endogenous metabolism and product formation is given by _____

(xv) Molecular weight cut off of a membrane is defined as _____

Group - B

2. (a) Derive the Briggs – Haldane equation for predicting the rate equation of homogeneous enzyme catalysed reaction. [[CO1] (Apply/LOCQ)]

(b) Discuss in details how both the Michaelis–Menten and Briggs–Haldane theories can be considered as the possible mechanism for homogeneous enzyme catalysed reaction. [[CO1] (Apply/LOCQ)]

6 + 6 = 12

3. (a) Discuss the different types of enzyme inhibition. Compare the effects of different types of enzyme inhibition on the Michaelis–Menten kinetic parameters. [[CO1](Understand/LOCQ)]

(b) 10 g of a plant material is extracted in 100 mL of a buffer. On performing assay for amylase activity, 100 µL extract produced 6 µmole glucose in 30 minutes of incubation. One unit of amylase activity is defined as the amount of enzyme required to produce 1 µmole of glucose per minute. Calculate the amylase activity in units/g. [[CO1](Analyse/IOCQ)]

(c) Urea dissolved in aqueous solution is degraded to ammonia and CO₂ by urease immobilized on surfaces on nonporous polymeric beads. Conversion rate is controlled by transfer of urea to surface of beads through liquid film and conversion takes place on surface of beads. Following parameters are given for

the system. $k_L=0.2$ cm/s, $K_m=200$ mg/l, $V_m'=0.1$ mg urea/cm² support. s, $S_b=1000$ mg urea/l

- (i) Determine the surface concentration of urea
- (ii) Determine the rate of urea degradation under mass transfer-controlled conditions.

[[CO4](Evaluate/HOCQ)]

5 + 3 + 4 = 12

Group - C

4. (a) “Microbial growth rate depends on nutrient concentration.” State True or False and justify.

[[CO3](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.

[[CO3](Apply/HOCQ)]

- (c) “Exponential phase is also known as balanced growth phase” Justify.

[[CO3](Analyze/IOCQ)]

3 + 7 + 2 = 12

5. (a) A fermentation broth with viscosity 10^{-2} Pa s and density 1000 kg/m³ is agitated in a 50 m³ baffled tank using a marine propeller 1.3 m diameter. Calculate the power requirement for a stirrer speed of 4 s⁻¹. The ratio of tank diameter to impeller diameter and the ratio of liquid height to tank diameter are 3. In the laminar regime, power number is inversely proportional to Reynolds number and in turbulent regime, power number is 0.35.

[[CO4](Analyse/HOCQ)]

- (b) “Growth rate varies linearly with oxygen transfer rate under oxygen limiting conditions” Justify.

[[CO4](Remember/LOCQ)]

- (c) Explain why the Monod constant K_s is known as the half velocity constant.

[[CO3](Apply/IOCQ)]

- (d) Explain what is meant by fermentation. Give examples of industrially important bioproducts.

[[CO3](Understand/LOCQ)]

4 + 3 + 2 + 3 = 12

Group - D

6. (a) A chemostat with recycle can be operated at dilution rates greater than maximum growth rate. Justify.

[[CO5](Analyse/IOCQ)]

- (b) A fed-batch bioreactor operates under quasi steady state.

[[CO5](Apply/IOCQ)]

- (c) Deduce the performance equation of a plug flow bioreactor used for conducting a microbial fermentation in terms of its residence time (τ_P).

[[CO5](Apply/IOCQ)]

(d) Discuss the importance of sterilization of a nutrient medium. *[[CO4](Understand/LOCQ)]*

3 + 3 + 3 + 3 = 12

7. (a) Derive the expression of steady state cell concentration obtained from a chemostat in terms of inlet substrate concentration and dilution rate in absence of product formation and endogenous metabolism. State the modification in the expression of cell concentration in presence of endogenous metabolism and product formation. *[[CO5](Analyse/IOCQ)]*

(b) Distinguish between active and passive cell immobilization. Discuss the advantages of cell immobilization. *[[CO4](Remember/LOCQ)]*

(c) A low value of Thiele modulus indicates minimum diffusional limitations in biofilm. Justify the statement with a proper diagram. *[[CO4](Apply/IOCQ)]*

(3 + 1) + (3 + 2) + 3 = 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. *[[CO6](Analyse/IOCQ)]*

(b) Discuss the process of protein purification using aqueous two phase extraction. *[[CO6](Remember/LOCQ)]*

(3 + 3) + 6 = 12

9. (a) A countercurrent extractor with four equilibrium stages is available for separating a desired bioproduct from a contaminating impurity, which is 10% of the weight of the bioproduct in a feedstream. For the extraction solvent being used, which is immiscible with the feedstream, the bioproduct has a partition coefficient K of 10, while the impurity has K=1. For a solvent to broth ratio of 0.2, what will be the ratio of impurity to bioproduct in the extract phase at the outlet of extractor? *[[CO6](Analyse/HOCQ)]*

(b) With a schematic diagram, explain the process of elution chromatography. *[[CO6](Remember/LOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	44.79	33.33	21.88