## Group – D

6. (a) Derive the performance equation of a mixed flow reactor in terms of substrate concentration and space time used for carrying out a microbial fermentation reaction following Monod equation.

(b) A fermentation reaction having the following rate equation

$R_c = \frac{1.2 C_A C_C}{C_A + 2}$ , $C_A$ = gm substrate/m³ and $Y_{C/A}$ = 0.1 gm cell/gm substrate is carried out in mixed flow reactor of volume 0.75m³. Find the outlet concentration of cells produced for optimum operation when 1 m³/h of substrate solution ($C_{A0}$ = 6 gm/m³) is fed to the reactor.

**6 + 6 = 12**

7. (a) Show that optimum cell concentration obtained in a chemostat is given by

$$C_{C_{opt}} = Y_{\frac{C}{A}} C_{A_0} \frac{N}{N-1} \text{ where } N^2 = \frac{K_S + C_{A_0}}{K_S}$$

(b) Discuss the different graphical methods used to determine intrinsic constants present in Monod equation.

**8 + 4 = 12**

## Group – E

8. (a) Classify different membrane separation processes used in bioseperation. Give a schematic diagram of a membrane separation unit and identify the components.

(b) What is concentration polarization?

**8 + 4 = 12**

9. (a) Classify different types of chromatographic techniques. Describe in details the column chromatographic process.

(b) Cell free fermentation liquor contains $8\times 10^{-5}$ mol/liter immunoglobulin G. It is proposed to recover 90% of this antibody by adsorption on synthetic, non polar resin. The equilibrium data are given by:

$$C^*_{AS} = 5.5x\,10^{-5} C^{*0.35}_A$$

Where $C^*_A$ is mol of solute adsorbed per cm³ adsorbent and $C^*_A$ is liquid phase solute concentration in mol / liter. What minimum quantity of resin is required to treat 2m³ fermentation liquor in a single stage mixed tank?

**6 + 6 = 12**





# BIOPROCESS ENGINEERING
# (CHEN 3233)

**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.***

***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) The plot of rate versus substrate concentration of an enzymatic reaction gives a section of rectangular hyperbola. The system represents a
(a) shifting order reaction
(b) first order reaction
(c) zero order reaction
(d) none of the above.

(ii) The maximum velocity ($V_m$) in Michaelis - Menten equation
(a) is an intrinsic kinetic parameter
(b) is not an intrinsic kinetic parameter
(c) depends strongly on pressure
(d) none of the above.

(iii) The Eadie- Hofstee plot gives slope equal to
(a) $V_m$ (b) $V_m / K_m$ (c) $-K_m$ (d) $K_m / V_m$.

(iv) Fed batch bioreactor is
(a) an unsteady state reactor
(b) a steady state reactor
(c) an isothermal reactor
(d) none of the above.

(v) The net effect of competition inhibition
(a) is an increase in the maximum velocity
(b) is a decrease in the maximum velocity
(c) is an increase in the apparent Michaelis - Menten constant
(d) is a decrease in the apparent Michaelis - Menten constant.

(vi) The Hanse - Woolf plot gives slope equal to
(a) $V_m$ (b) $1/V_m$ (c) $-K_m$ (d) $K_m / V_m$.

(vii) The Michaelis - Menten theory is based on the assumption that is used in
(a) homogeneous catalysis
(b) heterogeneous catalysis
(c) both homogeneous and heterogeneous catalysis
(d) none of the above.

(viii) The best combination of reactors to achieve the substrate concentration at the maximum cell growth rate is
(a) MFR followed by PFR
(b) PFR followed by MFR
(c) Two MFRs in series
(d) Two PFRs in series.

(ix) The intercept on abscissa of Lineweaver and Burk plot is equal to
(a) $1 / V_m$ (b) $-1 / K_m$ (c) $-K_m$ (d) $K_m / V_m$.

(x) Damkohler number ($D_a$) greate than 1 means
(a) the reaction rate is limiting
(b) the diffusion rate is limiting
(c) the diffusion and reaction resistances are comparable
(d) none of the above.

## Group – B

2. (a) Derive the rate equation of a substrate uninhibited enzymatic reaction using steady state assumption of Briggs - Halden theory.
The rate of urea conversion as a function of urea concentration in presence of enzyme urease is given below. Find the rate equation using Hanse – woolf method.

(b)

| Concentration of urea ($C_{urea}$), kmol/m$^3$ | 0.2 | 0.02 | 0.01 | 0.005 | 0.002 |
|---|---|---|---|---|---|
| Rate of urea conversion ($-r_{urea}$), kmol/m$^3$-s | 1.08 | 0.55 | 0.38 | 0.20 | 0.09 |

**6 + 6 = 12**





3. Cellulose can be converted to sugar by the following enzymatic attack Cellulose $\longrightarrow$ sugar (in presence enzyme cellulose) and cellubiose acts to inhibit the breakdown. To study the kinetics of this reaction a number of runs are made in an MFR kept at 50$^0$C and using a feed of finely shredded cellulose ($C_{A0}$ = 25 kg / m$^3$), enzyme ($C_{E0}$, same for all runs). The results are as follows:

| Run | Exit sream, $C_A$, kg / m$^3$ | Residence time with no inhibitor, min | Residence time with cellubiose, $C_{B0}$ = 5 kg / m$^3$, min |
|---|---|---|---|
| 1 | 1.5 | 587 | 691 |
| 2 | 4.5 | 279 | 306 |
| 3 | 9.0 | 171 | 182 |
| 4 | 21.0 | 36 | 38 |

Find a rate equation to represent this reaction.

**12**

## Group – C

4. (a) Discuss the importance of enzyme inhibition study in pharmacology. How Eadie Hofstee plot can be used to identify the nature of enzyme inhibition?

(b) Assume that experimental measurements for a certain organism have shown that cells can convert two-third (wt/wt) of the substrate carbon to biomass. Calculate the stoichiometric coefficients for the following biological reaction:

$$C_6H_{12}O_6 + aO_2 + b\,NH_3 \longrightarrow c\,(C_{4.4}H_{7.3}N_{0.86}O_{1.2}) + d\,H_2O + e\,CO_2$$

**6 + 6 = 12**

5. A specific bacterium lives and grows on lactose. In order to study the kinetic of this reaction, the following experimental data (in consistent units) were obtained from a batch reactor.

| Time (h) | 0 | 0.54 | 0.90 | 1.23 | 1.58 | 1.95 | 2.33 | 2.70 |
|---|---|---|---|---|---|---|---|---|
| Concentration of substrate ($C_A$) | 147 | 125 | 104 | 70 | 38 | 18 | 3 | 1 |
| Concentration of cell ($C_C$) | 15.5 | 23 | 30 | 38.8 | 48.5 | 58.3 | 61.3 | 62.5 |

Find a rate equation using Monod equation.

**12**