BIOPROCESS ENGINEERING
(CHEN 3141)

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) Experimental observation: 'v' versus 'S' for enzymatic reaction is a section of rectangle hyperbola whose equation is
(a) (a – v) (b + S) = constant
(b) (a + v) (b + S) = constant
(c) (a – v) (b - S) = constant
(d) None of the above

(ii) We have competitive inhibition when
(a) A (substrate) and B (inhibitor) attack on the same site on the enzyme
(b) when B attacks a different site on the enzyme, but in doing so stops the action of A.
(c) both (a) and (b)
(d) none of the above

(iii) The end product of Kreb's cycle is
(a) Oxaloacetic acid
(b) Maleic acid
(c) Succinic acid
(d) Ketoglutaric acid

(iv) An organism exhibits Monod growth with the following growth parameters: $\mu m=0.6\ h^{-1}$, Ks=4 g/l. The specific growth rate of the organism at a substrate concentration 2 g/l will be
(a) 0.2 h^{-1}
(b) 0.4 h^{-1}
(c) 0.3 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) The maximum yield for microbial conversion of glucose ($C_6H_{12}O_6$) to ethanol (C_2H_5OH) on mol/mol basis is approximately
(a) 1 (b) 3 (c) 0.5 (d) 2

(vii) The production of ethanol rather than biomass from yeast cells at high concentration is known as
(a) Warburg effect (b) Crabtree effect
(c) Simpson's effect (d) Olivosky's effect

(viii) In a laminar flow regime in non-gassed liquid, power number is
(a) Directly proportional to Reynolds number
(b) Inversely proportional to Reynolds number
(c) Independent of Reynolds number
(d) Does not bear a specific relation with Reynolds number

(ix) Volumetric productivities of batch reactor and chemostat are respectively
(a) $Y_{X/S}S_0/t_{batch}$ and $\mu_{max}Y_{X/S}S_0$ (b) $Y_{X/S}S_0$
(c) $Y_{X/S}S_0/t_{batch}$ and $Y_{X/S}S_0/\mu_{max}$ (d) $Y_{X/S}S_0t_{batch}$ and $\mu_{max}Y_{X/S}S_0$

(x) A fed-batch reactor operates on
(a) Steady state assumption (b) Unsteady state assumption
(c) Quasi steady-state assumption (d) Constant volume assumption.

Group- B

2. (a) Derive Michaelis Menten equation for free enzyme catalyzed reaction.
[(CO1) (Remember/LOCQ)]

(b) State the importance of enzyme inhibition study in pharmacology study.
[(CO1) (Understand/LOCQ)]

(c) The following data have been obtained for an enzyme - catalyzed reaction.

Substrate concentration, (gm / liter)	20.0	10.0	6.7	5.0	4.0	3.3	2.9	2.5
Rate (g/l-min) with C_{E0}= 0.015 gm/liter	1.14	0.87	0.70	0.59	0.50	0.44	0.39	0.35

Find the intrinsic kinetic parameters of Michaelis and Menten equation by Hanse-woolf method. [(CO1) (Evaluate/HOCQ)]

4 + 2 + 6 = 12

3. (a) Substrate A decomposes in the presence of enzyme E (A->R). It is desired to design a batch fermenter for producing 2000 kg R / day from a feed containing C_{A0} = 1000 mol / m³. The conversion of A is 90 %. The plant should operate day and night and times for filling, cleaning and draining may be taken as 0.5 hrs. The molecular weight of A is 179 and the initial enzyme concentration is 10 mol

/ m^3. Find the length and diameter of the reactor if the aspect ratio is 2 and the actual reactor volume is 25% excess of the theoretically calculated volume. The reactor is cylindrical in shape. The system follows Michaelis- Menten equation having k_3 and K_m values 48 hr^{-1} and 336 mol/m^3 respectively.

[(CO2) (Evaluate/HOCQ)]

(b) Cellulose can be converted to sugar by the following enzymatic attack Cellulose → 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 stream, 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. [(CO2) (Analyze/IOCQ)]

6 + 6 = 12

Group - C

4. (a) Justify the following statements as True or False:
   (i) Monod model of microorganism growth is an unstructured non-seggregated model.
   (ii) Increase in impeller speed and diameter causes proportionally greater power transmission to liquid in turbulent flow compared to laminar flow.
   (iii) Facilitated diffusion mechanism causes a transport of nutrients from low to high concentration. [(CO3) (Analyze/IOCQ)]

   (b) Discuss the steps of glycolysis calculating ATP balance of each step.

[(CO2, CO3)(Analyze/IOCQ)]

(2 + 2 + 3) + 5 = 12

5. (a) An engineer determined in her lab that the optimal productivity of a valuable antibiotic is achieved when the carbon nutrient is metered into a fermenter at a rate proportional to the growth rate. However, there was no reliable way to measure the growth rate dX/dt and biomass concentration (X) during the course of fermentation. It is suggested that an O_2 analyzer be installed on the plant fermenters so that the oxygen uptake rate (g/l-h) can be measured.
   (i) Derive expressions that may be used to estimate X and dX/dt from OUR and time data, assuming a simple yield and maintenance model can be used to describe the O2 consumption rate by the culture
   (ii) Calculate values of yield coefficient ($Y_{X/O2}$) and maintenance (m_{O2}) parameters from the following data.

Time	0	2	4	6	8	10	12	14	16	18	20	21
OUR	0.011	0.084	0.198	0.393	0.642	1.03	1.37	1.26	1.58	1.2	0.86	0.9

(g/h)											
X (g/l)	0.6	0.63	1.06	2.23	4.15	7.59	11.4	13	14.47	16.12	16.67	17.01

(mm graph required) [(CO3) (Evaluate/HOCQ)]

(b) (i) The constant Ks in the Monod equation is known as the half-velocity constant. Comment on the validity of the statement.

(ii) When oxygen transfer rate is rate-limiting, growth rate of the microorganism is proportional to oxygen transfer rate.

[(CO3)(Analyze/IOCQ)]

8 + (2 + 2) = 12

Group - D

6. (a) Justify the following statements:

(i) A chemostat with recycle can be operated at dilution rates greater than the maximum specific growth rate.

(ii) A fed-batch reactor operates under quasi-steady state.

[(CO2) (Analyze/IOCQ)]

(b) In a fed-batch culture operating with intermittent glucose addition, following parameter values are given at t=2 h when the system is at steady state.

V=1200 mL, F= 200 mL/h, S_0=100 g glucose/l, μ_{max}=0.3 h-1, K_s=0.1 glucose/l, $Y_{X/S}{}^{M}$=0.5 g dw cells/ g glucose, $X_0{}^{t}$=30 g.

(i) Find the initial volume of culture

(ii) Determine the concentration of growth limiting substrate at quasi steady state

(iii) Determine the concentration and total amount of biomass in the vessel at quasi steady state

(iv) If qp=0.2 g products/cells, P0=0, derive the expression of product concentration and determine the concentration at quasi steady state.

[(CO2) (Evaluate/HOCQ)]

(c) "Fractional viability in a batch reactor is constant for most of the exponential growth period". Comment on the validity of the statement.

[(CO2) (Analyze/IOCQ)]

(3 + 3) + 4 + 2 = 12

7. (a) "Treating the fermentation medium at high temperature for short time can bring about the same degree of sterilization as treating the medium at low temperature for long time" Comment on the validity of the statement.

[(CO3) (Analyze/IOCQ)]

(b) Distinguish between geometric, kinematic and dynamic similarities.

[(CO3) (Understand/LOCQ)]

(c) A stirred tank reactor is to be scaled down from 10 m^3 to 0.1 m^3. The dimensions of the large tank are: Dt= 2m, Di=0.5 m, N=100 rpm.

(i) Determine the dimensions of the small tank(Dt, Di, H) 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-(1) constant tip speed (2) constant Reynolds number. [(CO3)(Evaluate/HOCQ)]

3 + 3 + (3 + 3) = 12

Group - E

8. (a) With the aid of a flowsheet, describe the process of production of penicillin. [(CO4) (Remember/LOCQ)]

(b) In ultrafiltration of macromolecular solute the permeate flux increases monotonically with increase in pressure drop. [(CO3) (Analyze/IOCQ)]

(c) A feed with glucoamylase enzyme is purified in a cross-flow ultrafiltration module. The liquid phase mass transfer coefficient at the membrane surface is 2.5 × 10-5 m/s. Bulk concentration of the solute is 0.35 mass %. If solvent water flux is 0.38 m^3/m^2.h, calculate the polarization modulus and concentration of enzyme in the liquid at the membrane surface. The solute rejection by the membrane is 95%. If diffusivity of the enzyme is 6.7×10^{-7} cm2/s, calculate the film thickness. [(CO4)(Evaluate/HOCQ)]

6 + 3 + 3 = 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 the feedstream. For the extraction solvent being used which is immiscible with the feedstream, the bioproduct has a partition coefficient of 10, while the impurity has K=1. For a solvent to broth ratio 0.2, what will be the ratio of impurity to bioproduct in the extract phase at the outlet of the extractor? [(CO4) (Analyze/HOCQ)]

(b) "Multistage extraction is used to concentrate penicillin from fermentation broth." Comment on the validity of the statement. [(CO4) (Analyze/IOCQ)]

(c) Discuss the principles of elution chromatography. Explain the significance of breakthrough curve in adsorption of solutes. [(CO4)(Understand/IOCQ)]

5 + 3 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	15.63%	44.79%	39.58%

Course Outcome (CO):

After the completion of the course students will be able to

CO1: Solve biochemical reaction engineering problems for predicting rate equation for both enzymatic and live cell fermentation process

CO2: Design bioreactors for free enzymatic reaction under enzyme uninhibited/inhibited conditions

CO3: Select suitable bioreactor and its design and scale-up for whole cell catalysed reactions

CO4: Suitable modern separation techniques for isolation, purification, and quantitative separation of target biomolecule from live cells

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

Department & Section	**Submission Link**
CHE	https://classroom.google.com/c/NDA0OTAxMDk0ODAy/a/NDYzODQ5NTY3NjY2/details