Exam.Code:0912
Sub. Code: 33391

2055

B.E. (Biotechnology) Eighth Semester

BIO-814: Modeling and Simulation of Bioprocesses

Time allowed: 3 Hours **Max. Marks: 50**

NOTE: ***Attempt <u>five</u> questions in all, including Question No. 1 which is compulsory and selecting two questions from each Section. State clearly your assumptions.***

x-x-x

1) Write briefly:

a) Define metabolic Engineering and what are the significances?

b) Monod's Equation *vs* Michaelis-Menten equation?

c) Write down advantage and disadvantage of batch reactor.?

d) Define useful measurable parameter is the respiratory quotient (RQ) with suitable example?

e) Write down cell and substrate balance in fed batch reactor. (5×2)

SECTION-A

2. A) *Aspergillus niger* is used to convert glucose to gluconic acid via gluconolactone. If the conversion follows the first order consecutive reaction with K_1 and K_2 rate constant, derive the $\mathbf{t_{max}}$ at which the concentration of intermediate (gluconolactone) is maximized and also derive the maximum concentration ($\mathbf{C_{Lmax}}$) gluconolactone. Provided that the initial concentration of glucose at zero time G_0.

B) Water enters a tank at the rate of 26 L/min. it is being withdrawn at the rate which varies according to $26(1-e^{-0.1t})$ L/min., where t is minutes. If the tank initially contains 70 L. How many gallons (liter) of water will the tank contains when the steady state is reached? (6, 4)

3. A) Production of single- cell protein from hexadecane is described by the following reaction equation:

$$\mathbf{C_{16}H_{34} + aO_2 + bNH_3 \rightarrow cCH_{1.66}O_{0.27}N_{0.20} + dCO_2 + eH_2O}$$

Where $cCH_{1.66}O_{0.27}N_{0.20}$ represents the biomass, If RQ = 0.34 determine the stoichiometric coefficients.

B) Dean and Hinshelwood proposed two-compartment model shown bellow for a bacterial cell.

$$\boxed{\frac{dX_1}{dt} = \alpha_1 X_2} \quad \rightleftharpoons \quad \boxed{\frac{dX_2}{dt} = \alpha_2 X_1}$$

The rate of changes of component $X_1$and X_2 follow the equations shown in the boxes above with α_1 and α_2 being kinetic constants. Solve this model of X_1 and X_2 with time t for the cases:

$\alpha_1 = \alpha_2$; and $\alpha_1 \rangle \alpha_2$ (6, 4)

4. A) An enzyme is used to produce a compound that is further used to manufacture sunscreen lotion. V_{max} for enzyme 2.5 m mol/m^3-s, K_m = 8.9 mM. The initial concentration of substrate is 12 mM. If the reaction is being carried out under isothermal conditions, what batch reaction time is required for 90% substrate conversion and if the enzyme used in deactivates with half life of 4.4 hr, what is the batch reaction time required to achieve 90% substrate conversion?

B) A tank contains 1000 liters of pure water. Brine that contains 0.05 kg of salt per liter of water enters the tank at a rate of 5 liters/min. Brine that contains 0.04 kg of salt per liter of water enters the tank at the rate of 10 liters/min. The solution is kept thoroughly mixed and drains from the tank at 15 liters/min. How much salt is left in the tank after 1 hour?

(5, 5)

SECTION-B

5. A) Fermentation by *Candida utilis*exhibits substrate inhibition kinetics in the form:

$$\mu = \frac{\mu_{max}.S}{K_s + S + S^2/K_I}$$

Where S is the substrate, μ is the specific growth rate and μ_{max} is the maximum specific growth rate. For continuous fermentation using sterile feed, derive equation for the steady state variation of the biomass concentration (X), Substrate concentration (S) and their maximum productivity (DX).

B) In fed-batch fermentor, substrate stream is added continuously to the reactor. Develop a suitable mathematical model with the following kinetics:

$$r_X = \mu X, \quad \mu = \frac{\mu_{max} S}{K_S + S}, \quad r_S = -\frac{r_X}{Y}, \quad D = \frac{F_0}{V}$$

Convert the model in the dimensionless using the following transformation:

$$V' = \frac{V}{V_0}, \quad X' = \frac{X}{YS_0}, \quad S' = \frac{S}{S_0}, \quad F' = \frac{F_0}{V_o \mu}, \quad K'_S = \frac{K_S}{S_0}, \quad \mu' = \frac{\mu}{\mu_m}, \quad F' = \frac{dV'}{dt'}$$

and $t' = t\mu_m$

(5, 5)

6. A) The *Zymomonas mobilis* used to convert glucose to ethanol in batch fermenter under anaerobic conditions. The yield of biomass from substrate is 0.06 g g^{-1}, specific rate of product formation is 3.4h^{-1}, and maximum specific growth rate of *Zymomonas mobilis* is approximately 0.3 h^{-1}. 5 g bacteria are inoculated into 50 liters of medium containing 12 gL^{-1}glucose. Determine the batch culture time required to

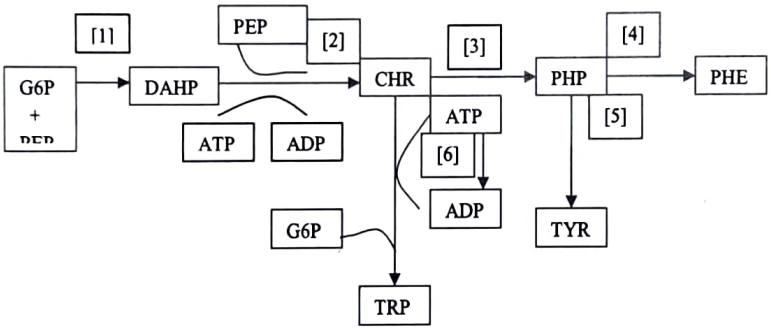
i) Produce 15 g biomass

ii) Achieve 90% substrate conversion and

iii) Produce 100 g ethanol.

B) An arrangement consists of two stirred tanks reactor connected in series. The first reactor has an operational volume of 75 liters and the second reactor having an operational volume of 25 liters. A sterile feed is given to the first rector containing 3.5 g/liter of substrate and fed at the rate of 15 liters/ hr. Using Monod's kinetic model to describe the growth kinetics, it is found that the value of K_s is 0.11 g/liter, $Y_{x/s}$ is 0.4 and maximum specific growth rate is 0.22 hr^{-1}. Determine the steady state concentration of substrate in the second reactor. *(4, 6)*

7. A) The metabolic pathway for aromatic amino acid synthesis is given bellow; identify the substrates, products, intermediates. Construct the stoichiometric model and develop the matrix form.



The simplified metabolic pathway for aromatic amino acid synthesis by *S.cerevisiae.*
The chemical species are G6P = glucose-6-phosphate, PEP = phosphenol pyruvate, DHAP= 3-deoxy-D-arabinoheptulosonate-7-phosphate, CHR = chroismatee, PHP = prephanate, PH E= phylalanin, TYR = tyrosin, TRP = tryptophan.

B) Discuss the Monod chemostat model with recycle system. *(6, 4)*

x-x-x