ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2017 SESSION

- All documents allowed
- Calculator: authorized models only
- Examination duration: 3 hours
- One (1) sheet of millimetered paper required

16-CH-A7 BIOCHEMICAL ENGINEERING (total: 100 points)

QUESTION 1 (5+5+10 = 20 points): enzyme inhibition kinetics (millimetered page required)

The initial rate of reaction of an enzyme catalyzed reaction was determined in the presence of several inhibitors, A, B and C, at various concentrations of substrate, S. The data in the presence and absence of each inhibitor are shown in the table below. Determine the manner of action of each inhibitor and calculate the kinetic constants r_{MAX}, K_M (Michaelis-Menten parameters) and K_i (inhibition constant) for A, B and C, if the total enzyme concentration is 2 µM.

S (mM)	r (µM/min)			
	Without inhibition	With A at 25 mM	With B at 30 mM	With C at 20 mM
0,1	27	14	14	25
0,2	50	27	25	43
0,5	100	60	50	75
1	150	100	75	100
2	200	150	100	120
5	250	214	125	136
10	273	250	136	143
20	286	273	143	146

a) Plot the graphs that are required to identify the enzyme kinetics and the inhibition type; Indicate any useful information on this graph;

b) Estimate the value of the enzyme kinetic parameters without inhibition;

c) Determine each inhibition type caused by A, B and C (competitive, non-competitive or uncompetitive) and estimate their parameters, K_i.

QUESTION 2 (5+5+5+5+5+10+5 = 40 points): Microbial batch growth

A new bacterium strain, *P. quebecensis*, has been found to very useful for the treatment of soluble wastes from the maple syrup industry. Its kinetics has been characterized. It has been found that this microorganism follows a substrate inhibition rate law (Haldane) of the form:

$$\mu = \frac{\mu_{MAX} \cdot S}{K_M + S + S^2 / K_{S,i}}$$

Where μ is the specific growth rate (h^{-1}), S is the only limiting substrate concentration (g/L), and μ_{MAX}, K_M and $K_{S,i}$ are the three parameters of that kinetic law, of values 0,92 h^{-1}, 10 g/L and 10 g/L respectively.

You plan to grow P. Quebecensis in a closed system (a batch fermenter) with an initial concentration of biomass X_0 = 0,2 g/L and of substrate, S_0 = 50 g/L. Before doing so, you want to predict mathematically the evolution of the biomass concentration (X, g/L) during this fermentation.

a) Assuming a constant substrate to yield coefficient ($Y_{X/S}$) of 0,4 g/g, how could you relate mathematically X to S during the fermentation (develop that relation based on a substrate mass balance)?

b) Using the equation developed in (a), calculate the maximum X value the fermentation would attain;

c) Calculate the effective maximum specific growth rate this culture would reach;

d) Write the differential balance equation for X, using the microorganism growth rate law;

e) Substitute in the equation developed in (c) the relation for S developed in (a);

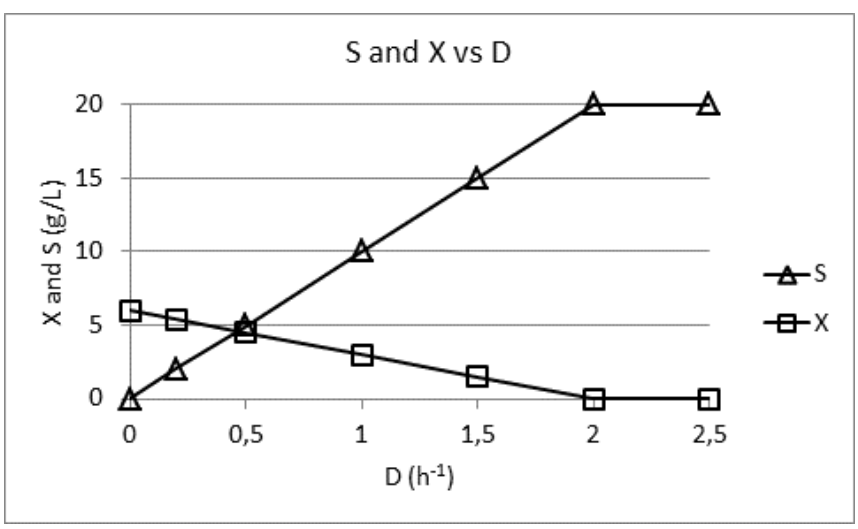
f) Solve the differential equation developed in (d) (you might need to used partial fraction decomposition to do so);

g) Using the equation developed in (e), calculate the time required for the fermentation to reach a point where 50% of the substrate would be converted to microorganism.

.

QUESTION 3 (5+5+5+5+10 = 30 points): Chemostat fermentation

You are provided with the graph below about a very interesting microorganism that produces a new biofuel. From these data, obtained in steady state chemostat (continuous) cultures for different dilution rates (D, in h^{-1}), limiting substrate (S) and biomass (X) concentrations:



a) Determine the washout dilution rate;

b) Determine the feed substrate concentration;

c) Determine the cell to substrate yield coefficient ($Y_{X/S}$);

d) Determine this microorganism growth kinetic law and estimate the parameters of that relation;

e) Assuming that the production rate of the biofuel expressed by this microorganism obey a Luedeking-Piret law:

$$q_P = \alpha \cdot \mu + \beta$$

where q_p is the specific production rate of the fuel (g product · g microorganism^{-1} · h^{-1}) and μ is the specific growth rate of the microorganism (h^{-1}), with α = 0,2 (g product / g microorganism) and β = 0,02 g product · g microorganism^{-1} · d^{-1}. Identify the dilution rate at which maximum volumetric productivity will be attain and provide the value of that productivity.

QUESTION 4 (10 points): General questions

a) Describe the general effect that micro-organism maintenance energy consumption would have on a fermentation;

b) Describe what would be the effect of a constant cell death rate on a chemostat fermentation;

c) Describe what diauxic cell growth is;

d) Describe what an autotrophic micro-organism is;

e) Describe what an anaerobic micro-organism is.