DEPARTMENT OF BIOCHEMICAL ENGINEERING & BIO TECHNOLOGY

Introduction to Biochemical Engineering (CHL291)

Major Examination

Time: 8:00 h-10:00 h
Venue: II 378
Date: November 28, 2006
Total Marks: 40

Attempt all Questions

1. For the reversible reaction

$$E + S \underset{k_{-1}}{\overset{k_1}{\longleftrightarrow}} ES \underset{k_{-2}}{\overset{k_2}{\longleftrightarrow}} E + P$$

Show that

(a) The reaction will proceed far to the right only if $k_1 k_2 > k_{-1} k_{-2}$

(b) The parameters v_s, v_p, K_s, K_p are not independent.

(c) Under what conditions will a Lineweaver-Burk plot of the equation in part (b) yield useful result?

(d) Integrate dp/dt above to obtain $p(t)$ in terms of t and the value of p at equilibrium $At = Bp + C \ln\left(1 - \frac{p}{p_{eq}}\right)$ *where A, B and C are constants*.

(e) If $K_s = K_p$ show that $B = 0$

[8]

2. For some populations, a minimum level of substrate may be needed to achieve a nontrivial steady state. As an example, consider the system with kinetics of the form:

$$r_x = \frac{dx}{dt} = \frac{\mu_m s x}{K_s + s} - k_e x \quad r_s = -\frac{ds}{dt} = \frac{1}{Y_{x/s}} \frac{\mu_m s x}{K_s + s}$$

(a) Show that at substrate level below $k_e K_s / (\mu_m - k_e)$ the only steady state in a continuous culture system is $x = 0$.

(b) If $\mu_m = 0.5 h^{-1}$, $K_s = 0.2 g/l$, $k_e = 0.1 h^{-1}$, *and* $Y_{x/s} = 0.6$, plot $(dx/dt)_{batch}$ vs x and prove by direct solution of the above equations that $dx/dt = 0$ for low s and for $D > D_{washout}$

[8]

3. Dimensions of a bioreactor equipped with two sets of standard flat blade turbines and four baffle plates are: bioreactor diameter $D_t = 3m$, impeller diameter $D_i = 1.5m$, baffle plate width $W_b = 0.3m$ and liquid depth $H_L = 5m$. The bioreactor is used for a specific bioconversion. The viscosity and the density of the broth are $0.02 kg/m\,s$ and

$1200\,kg/m^3$ respectively. Rotation speed of impellers and aeration rate are $60\,rpm$ and $0.4\,vvm$ respectively. Calculate ($N_p = 0.6$)

(a) Power requirements for ungassed system
(b) Power requirements when aerated.
(c) Volumetric coefficient of oxygen transfer.
(d) Hold-up of bubbles.

[6]

4. The following table pertains to continuous culture data of *E. coli* grown aerobically having glucose as the growth limiting substrate with initial concentration is 0.968 kg/m^3.

Dilution rate (h^{-1})	Substrate concentration (kg/m^3)	Cell concentration (kg/m^3)
0.06	0.006	0.427
0.12	0.013	0.434
0.24	0.033	0.417
0.31	0.04	0.438
0.43	0.064	0.422
0.53	0.102	0.427
0.60	0.122	0.434
0.66	0.153	0.422
0.69	0.170	0.430
0.71	0.221	0.390
0.73	0.210	0.352

Estimate the following

(a) Maximum specific growth rate and saturation constant
(b) Maintenance coefficient and true growth yield coefficient
(c) Specific oxygen uptake rate

[9]

5. A freshly prepared fermentation medium was found to have 10^{10} viable cells per liter. Quality control protocol for the fermentation under consideration stipulates that the medium at the time of inoculation should not have more than one viable cell in 10 liters. This is to be achieved through a batch sterilization process. The medium at 30^0C is to be heated to 121^0C, held at that condition for a pre-determined time span and then cooled down to 30^0C. Heating and cooling operations are carried out at a temperature programming of 2^0C per minute and 1^0C per minute respectively. If the thermal deactivation rate constant (k_d) can be taken as $k_d = 8.5\,x\,10^{-4}(T) - 0.03825$ for $T \geq 45^0C$. Calculate the minimum time required for sterilizing one batch of medium.

[9]