

Due: Monday December 8 at 11:30 am

1. Consider the growth of *Enterobacter aerogenes* in each of two independent chemostat operations, each of volume 500 L, each operating at steady state. Cell maintenance effects in each bioreactor are negligible, and product formation in each bioreactor is negligible. Growth of *E. aerogenes* in each bioreactor is limited by ammonium ion, such that $\mu = (\mu_{max} S)/(K_S + S + S^2/K_I)$, where $\mu_{max} = 0.23 \text{ h}^{-1}$, $K_S = 0.16 \text{ g/L}$, and $K_I = 28 \text{ g/L}$. Mass transfer limitations in each bioreactor are negligible. Finally, in each bioreactor, the feed is sterile and inlet flow rates are identical with $S_0 = 4.8 \text{ g/L}$, but substrate conversions are not the same.

In responding to parts (a) through (h) below, if any quantity requested cannot be determined based on the information provided, briefly explain why that is so.

- (5) a. If ammonium conversion in bioreactor 1 is 70%, determine the ammonium conversion in bioreactor 2.
- (5) b. Determine whether the cell concentration in bioreactor 1 would be less than, equal to, or greater than the cell concentration in bioreactor 2.
- (5) c. Determine whether $Y_{X/S,obs}$ in bioreactor 1 would be less than, equal to, or greater than $Y_{X/S,obs}$ in bioreactor 2.
- (5) d. Determine whether $Y_{X/S,obs}$ in either bioreactor would be expected to change with a change in flow rate.

Now suppose cell maintenance effects are not negligible, such that maintenance is achieved entirely by endogenous metabolism, with $k_d = 0.030 \text{ h}^{-1}$.

- (4) e. If ammonium conversion in bioreactor 1 is 70%, determine the ammonium conversion in bioreactor 2.
- (4) f. Determine whether the cell concentration in bioreactor 1 would be less than, equal to, or greater than the cell concentration in bioreactor 2.
- (4) g. Determine whether $Y_{X/S,obs}$ in bioreactor 1 would be less than, equal to, or greater than $Y_{X/S,obs}$ in bioreactor 2.
- (4) h. Determine whether $Y_{X/S,obs}$ in either bioreactor would be expected to change with a change in flow rate.

2. Consider again Problem 6.7 in Shuler and Kargi. Assuming maintenance is achieved entirely by endogenous metabolism, analysis of the given data showed that $\mu_{max} = 0.95 \text{ h}^{-1}$ and $K_S = 0.141 \text{ mg/mL}$. On the other hand, assuming maintenance is achieved entirely by substrate consumption, analysis of the given data showed that $\mu_{max} = 2.3 \text{ h}^{-1}$ and $K_S = 0.548 \text{ mg/mL}$. Using no more than two sentences in each case, clearly describe why the outcomes stated below are to be expected.
- (10) a. The value of μ_{max} estimated under the assumption of maintenance by substrate consumption was greater than that estimated under the assumption of maintenance by endogenous metabolism.
- (10) b. The value of K_S estimated under the assumption of maintenance by substrate consumption was greater than that estimated under the assumption of maintenance by endogenous metabolism.

3. A waste water stream containing soluble contaminant species at 30 g/L is to be treated using bacteria immobilized in porous beads. The kinetics of contaminant conversion by this immobilized culture is subject to inhibition by contaminant according to

$$r = \eta(r_m S)/(K_S + S + S^2/K_I),$$

where $r_m = 32.8$ g contaminant consumed/L of liquid/h, $K_S = 0.24$ g/L and $K_I = 40$ g/L. While the effects of external mass transfer limitations on contaminant transport are negligible, we know that mass transfer limitations will be present within the pores of the beads.

- (10) a. Derive the expression for the residence time required to achieve a specified extent of contaminant conversion in a batch bioreactor. For this purpose you may consider η to be an average value characteristic of this particular operation.

- (9) b. Indicate whether η would change or remain constant with residence time in each bioreactor configuration identified below, or indicate that this cannot be determined. Provide a brief justification with each response.

packed bed bioreactor INCREASE DECREASE REMAIN CONSTANT CANNOT BE DETERMINED

chemostat INCREASE DECREASE REMAIN CONSTANT CANNOT BE DETERMINED

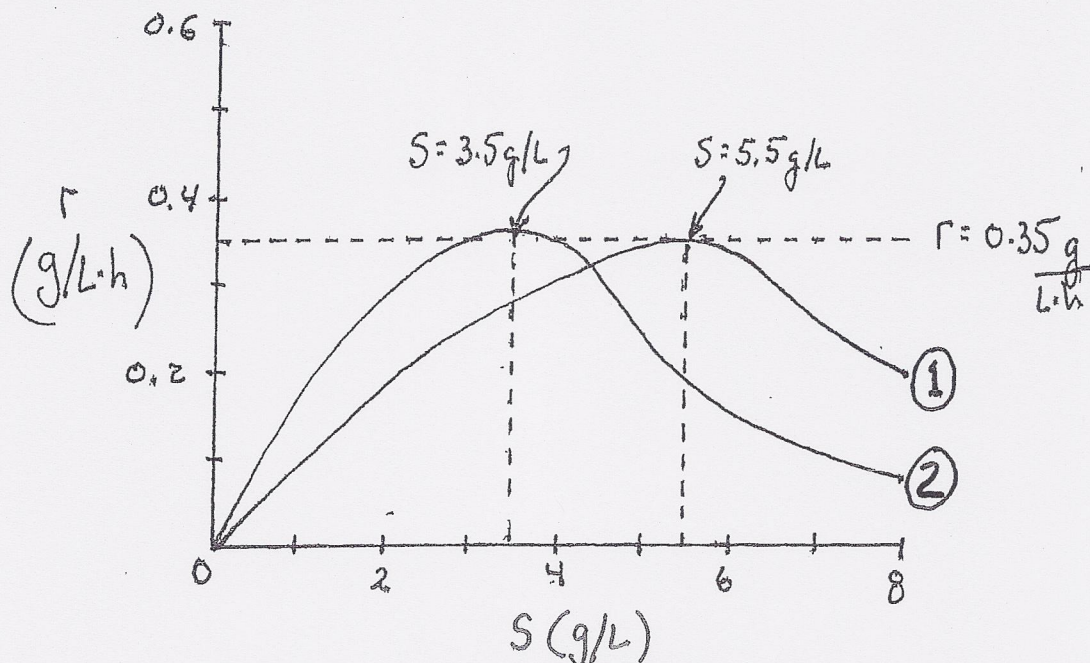
batch bioreactor INCREASE DECREASE REMAIN CONSTANT CANNOT BE DETERMINED

- (10) c. Suppose we will be required to achieve 95% contaminant conversion in this treatment process. State whether it is possible to operate with the same residence time and produce the same (95%) contaminant conversion in each reactor for the following cases. Provide a quantitative justification for each response.

packed bed bioreactor vs. batch bioreactor

chemostat vs. batch bioreactor

4. Consider the plots of r vs. S below (labeled "1" and "2"), sketched for substrate consumption in a particular immobilized cell system subject to substrate inhibition. In one case the rate of substrate consumption is plotted as a function of average substrate concentration in the pores (S_{pore}), and in the other case the rate is plotted as a function of the bulk substrate concentration (S_b).



- (5) a. Within the range of substrate concentration shown, specify the value of S_b – and corresponding value of S_{pore} – at which there are no mass transfer limitations, or state that no such condition exists.
- (5) b. Within the range of substrate concentration shown, specify the value of S_b – and corresponding value of S_{pore} – at which $\eta = 1$, or state that no such condition exists.
- (5) c. At the optimal bulk substrate concentration (i.e., the value of S_b corresponding to the maximum rate of substrate consumption), specify the values of S_{pore} and η .