concentration of $S_0 = 2$ g/l. The effluent lactose concentration is desired to be $S = 0.1$ g/l. If the growth rate is limited by oxygen transfer, by using the following information:

$$Y^M_{X/S} = 0.45 gX/gS, \quad Y^M_{X/O_2} = 0.25 gX/gO_2 \text{ and } C^* = 8\text{mg/l}$$

**a.** Determine the steady-state biomass concentration ($X$) and the specific rate of oxygen consumption ($q_{O_2}$).

**b.** What should be the oxygen-transfer coefficient ($k_La$) in order to overcome oxygen-transfer limitation (i.e., $C_L = 2$ mg/l)?

**6.14.** The maximum growth yield coefficient for *Bacillus subtilis* growing on methanol is 0.4 g $X$/g $S$. The heat of combustion of cells is 21 kJ/g cells and for substrate it is 7.3 kcal/g. Determine the metabolic heat generated by the cells per unit mass of methanol consumption.

**6.15.** Calculate the productivity (i.e., DP) of a chemostat under the following conditions:

**1.** Assume Monod kinetics apply. Assume that negligible amounts of biomass must be converted to product (< 1%).

**2.** Assume the Luedeking–Piert equation for product formation (eq. 6.18) applies.

**3.** Assume steady state:

| | |
|---|---|
| $D = 0.8\mu_m$ | $Y^M_{X/S} = 0.5$ g $X$/g $S$ |
| $\mu_m = 1.0$ h$^{-1}$ | $S_0 = 1000$ mg/l |
| $K_s = 10$ mg/l | $\beta = 0.5$ h$^{-1}$ mg $P$/g $X$ |
| $\alpha = 0.4$ mg $P$/g $X$ | |

**6.16.** Consider a chemostat. You wish to know the *number* of cells in the reactor and the *fraction* of the cells that are viable (i.e., alive as determined by ability to divide).

**a.** Write an equation for viable cell number ($n_v$). Assume that

$$\mu_{\text{net,rep.}} = \frac{\mu_{\text{m,rep}} S}{K_{\text{s,rep}} + S} - k'_d$$

where $\mu_{\text{net,rep}}$ = net specific replication rate, $\mu_{m,\text{rep}}$ = maximum specific replication rate, and $k'_d$ = death rate. $K_{s,\text{rep}}$ is the saturation parameter.

**b.** Derive an expression for the value of $S$ at steady state.

**c.** Write the number balance in the chemostat on dead cells ($n_d$).

**d.** Derive an expression for the fraction of the total population which are dead cells.

**6.17.** *E. coli* is cultivated in continuous culture under aerobic conditions with a glucose limitation. When the system is operated at $D = 0.2$ h$^{-1}$, determine the effluent glucose and biomass concentrations by using the following equations ($S_0 = 5$ g/l):

**a.** Monod equation: $\mu_m = 0.25$ h$^{-1}$, $K_s = 100$ mg/l.

**b.** Tessier equation: $\mu_m = 0.25$ h$^{-1}$, $K = 0.005$ (mg/l)$^{-1}$.

**c.** Moser equation: $\mu_m = 0.25$ h$^{-1}$, $K_s = 100$ mg/l, $n = 1.5$.

**d.** Contois equation: $\mu_m = 0.25$ h$^{-1}$, $K_{sx} = 0.04$, $Y^M_{X/S} = 0.4$ g $X$/g $S$.

$$S_0 = 5 \text{ g/l}$$

Compare and comment on the results.

**6.18.** Consider steady-state operation of a chemostat. Assume that growth is substrate inhibited and that endogeneous metabolism can be ignored such that:

$$\mu_{\text{net}} = \frac{\mu_m S}{K_S + S + S^2 / K_I}$$