Examples Chapter Transfer Phenomena

Example 1: Cell concentration in aerobic culture

A strain of *Azotobacter vinelandii* is cultured in a 15m^3 stirred Fermenter for alginate production. Under current operating conditions k_La is 0.17 s^{-1}. Oxygen solubility in the broth is approx. 8 x 10^{-3} kg m^{-3}.

a) The specific rate of oxygen uptake is 12.5 mmol g^{-1} h^{-1}. What is the maximum possible cell concentration?
b) The bacteria suffer growth inhibition after copper sulphate is accidently added to the fermentation broth. This causes a reduction in oxygen uptake rate to 3 mmol g^{-1} h^{-1}. What maximum cell concentration can now be supported by the fermenter?

Solution

A strain of *Azotobacter vinelandii* is cultured in a 15 m^3 stirred fermenter for alginate production. Under current operating conditions $k_L a$ is 0.17 s^{-1}. Oxygen solubility in the broth is approximately 8×10^{-3} kg m^{-3}.

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Solution:

(a) From

$$x_{max} = \frac{(0.17\ s^{-1})\ (8 \times 10^{-3}\ kg\ m^{-3})}{\frac{12.5\ mmol}{g\ h} \cdot \left| \frac{1\ h}{3600\ s} \right| \cdot \left| \frac{1\ gmol}{1000\ mmol} \right| \cdot \left| \frac{32\ g}{1\ gmol} \right| \cdot \left| \frac{1\ kg}{1000\ g} \right|}$$
$$= 1.2 \times 10^4\ g\ m^{-3} = 12\ g\ l^{-1}.$$

(b) Assume that addition of copper sulphate does not affect C^*_{AL} or $k_L a$. If q_O is reduced by a factor of $12.5/3 = 4.167$, x_{max} is increased to:

$$x_{max} = 4.167\ (12\ g\ l^{-1}) = 50\ g\ l^{-1}.$$

To achieve the calculated cell densities all other conditions must be favourable, e.g. sufficient substrate and time must be provided.

Example 2: Specific oxygen uptake in *E.coli culture*

It is assumed, that the specific oxygen uptake rate (qO_2) of *E. coli* is 5.0 mmol g^{-1} h^{-1}. Which cell concentration X can be reached in a laboratory reactor with a k_La of 25 h^{-1}. When C_L = 10 % C*. and for the medium at 37 °C is C* = 0.17 mmol L^{-1}

Solution:

$OTR = x\ qO_2$

with $C_L = 0.1\ C^*$

$OTR = 25\ (0.17 - 0.017)$ mmol L^{-1} h^{-1} = 3.8 mmol L^{-1} h^{-1}

And $X_{max} = 3.8 / 5.0 = 0.76$ g L^{-1}

Example 3:

1. Estimate how fast the dissolved oxygen concentration is consumed in a bioreactor with KLa 1000 h-1, containing a 10 g/L culture growing with $\mu = 0.5\ h^{-1}$ if the aeration is interrupted.

First calculate the quasi-steady state oxygen concentration. Assume $Y_{X/O} = 1$ g/g and the oxygen solubility in the medium equilibrium with air C* = 7 mg/L

Solution:

$$\frac{dC}{dt} = K_L a\,(C^* - C) - q_O X$$

$$\frac{dC}{dt} << q_O X \text{ and } q_O = \mu / Y_{X/O} \longrightarrow C = 0.002$$

$$time = \frac{C}{r_O}\,hrs = \frac{0.002 * 3600}{0.5/1*10} = 1.4\ sec$$

This calculation assumes that the consumption rate is constant also at very low oxygen concentration.

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Because of quasi ss: Dc/dt 0= 0 -> kla (c*-c) = qO2 X

-> 1000 /h (0.007 g/L - ?) = qO2 10 g/L

qO2 = mue / Yxo

1000 (0.007 - ?) = 0.5/1 . 10 -> C = 0.002

dc/dt = ro -> time = dc /ro = dc/mue $(Yxo)^{-1}$ x

Or dO/dt = qO X -> dt = dO / qO X

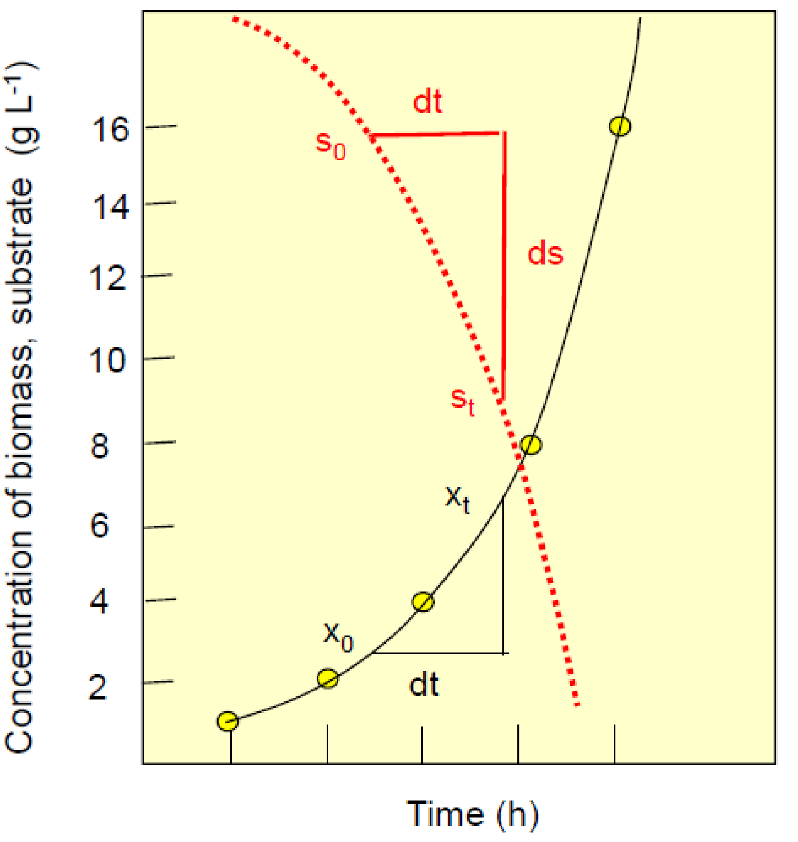
Help: Oxygen is a substrate S = O

(13) $$Y_{X/S} = \frac{x - x_0}{s_0 - s} = \frac{\Delta x}{\Delta s}$$

(14) $$q_s = \frac{ds}{dt} \cdot \frac{1}{x}$$

(15) $$q_s = \frac{\mu}{Y_{X/S}}$$

(16) $$-\frac{dS}{dt} = q_s \cdot X$$



$Y_{x/s}$ = growth yield
q_s = specific substrate consumption rate