

Bioreactors
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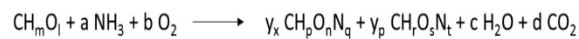
Lecture – 19
Solution to pp 5.1

Welcome to lecture number 19, NPTEL online certification course on bioreactors.

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Practice problem 5.1.

Let us consider the same stoichiometry as earlier:



Estimate the cell-oxygen yield co-efficient, $Y_{x/o}$ defined as the ratio of the amount of cells produced to the amount of oxygen consumed, in terms of the relevant ones

among $\Gamma_s, \Gamma_x, \Gamma_p$ (ϵ, η, ζ)

Assume that the mass fraction of carbon in cells (biomass) is 0.5

Practice problem 5.1.

For the following equation



Estimate the cell-oxygen yield co-efficient, $Y_{x/o}$ defined as the ratio of the amount of cells produced to the amount of oxygen consumed, in terms of the relevant ones among $\Gamma_s, \Gamma_x, \Gamma_p$ (ϵ, η, ζ).

Assume that the mass fraction of carbon in cells (biomass) is 0.5

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What is needed?

Y_{x/O_2} in terms of the various quantities that we defined

What is known/given?

$$CH_mO_l + a NH_3 + b O_2 \longrightarrow y_x CH_pO_nN_q + y_p CH_rO_sN_t + c H_2O + d CO_2$$

Mass fraction of C in biomass = 0.5

How to connect what is needed to what is given?

$$Y_{x/O_2} = \frac{\text{mass of cells (biomass) produced}}{\text{mass of oxygen consumed}}$$

What is needed, our usual first question; Y_{x/O_2} in terms of the various quantities that we have defined is what we need. What is known, or given, the stoichiometric equation is known; the mass fraction of carbon in biomass is 0.5. And, how do we connect what is needed to what is given. We know that Y_{x/O_2} , yield of cells with respect to oxygen, by definition is mass of cells or biomass produced, divided by the mass of oxygen that is consumed.

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From the stoichiometry equation, the biomass produced contains y_x moles of C
or $(12 y_x)$ g of C

If the mass fraction of C in biomass is 0.5, the biomass produced is $\frac{12 y_x}{0.5}$

Unitary method: if 0.5 is 12 y_x what is 1.0?

From the above shown stoichiometric equation, the oxygen requirement for every mole of substrate is b moles = $32b$ g

Thus,
$$Y_{x/o_2} = \frac{\left(\frac{12 y_x}{0.5}\right)}{32 b}$$

b and y_x are specific for a given stoichiometry. But, the parameters, $\Gamma_s, \Gamma_x, \Gamma_p$ and the fraction of electrons transferred to oxygen, biomass (cells) and product (ϵ, η, ζ) can be generalized. We already know that for a wide variety of cells $\Gamma_x \approx 4.2$

From the stoichiometric equation,

the biomass produced contains y_x moles of C, or $12 y_x$ grams of C.

If the mass fraction of C in biomass is 0.5, the biomass produced is $\frac{12y_x}{0.5}$

Also from the stoichiometric equation, we can derive that the oxygen requirement for every mole of substrate is b moles which when converted to mass is $32b$ grams.

Thus we can write

$$Y_{\frac{x}{o_2}} = \frac{\frac{12y_x}{0.5}}{32b}$$

b and y_x are specific for a given stoichiometry but $\Gamma_s, \Gamma_x, \Gamma_p, \epsilon, \eta, \zeta$ can be generalized.

We already know that, for a variety of cells $\Gamma_x = 4.2$.

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From our formulation, we know that $\frac{4b}{\Gamma_s} + y_x \frac{\Gamma_x}{\Gamma_s} + y_p \frac{\Gamma_p}{\Gamma_s} = 1$

We had defined $\frac{4b}{\Gamma_s} = \epsilon$ $y_x \frac{\Gamma_x}{\Gamma_s} = \eta$ $y_p \frac{\Gamma_p}{\Gamma_s} = \zeta$

So $\epsilon + \eta + \zeta = 1$

Thus $Y_{x/o_2} = \frac{\left(\frac{12 y_x}{0.5}\right)}{32 b} = \frac{24 \eta \frac{\Gamma_s}{\Gamma_x}}{32 \epsilon \frac{\Gamma_s}{4}} = \frac{24 \eta}{8 \epsilon \Gamma_x} = \frac{3 \eta}{8 \Gamma_x (1 - \eta - \zeta)}$

From our formulation, we know that

$$\frac{4b}{\Gamma_s} + y_x \frac{\Gamma_x}{\Gamma_s} + y_p \frac{\Gamma_p}{\Gamma_s} = 1 \text{ or}$$

$$\epsilon + \eta + \zeta = 1$$

We saw above that

$$Y_{\frac{x}{o_2}} = \frac{\frac{12 y_x}{0.5}}{32 b}$$

Substitute for y_x and b in terms of η and ϵ respectively to get

$$Y_{\frac{x}{o_2}} = \frac{\frac{12 y_x}{0.5}}{32 b} = \frac{24 \eta \frac{\Gamma_s}{\Gamma_x}}{32 \epsilon \frac{\Gamma_s}{4}} = \frac{24 \eta}{8 \epsilon \Gamma_x}$$

After substituting for ϵ , we get,

$$Y_{\frac{x}{o_2}} = \frac{3\eta}{\Gamma_x (1 - \eta - \zeta)}$$

Therefore, oxygen uptake rates can be estimated from biomass formation data.