Aerobic production of a single extracellular product

$CH_mO_n + a\,O_2 + b\,NH_3 \rightarrow$

substrate (s)

$c\,CH_\alpha O_\beta N_\delta + d\,CH_xO_yN_z + e\,H_2O + f\,CO_2$ Eq(4)

biomass (b) product (p)

C : $1 = c + d + f$

N : $b = c\,\delta + d\,z$

O :

H :

e^- : $\gamma_s - 4a = c\,\gamma_b + d\,\gamma_p$ (γ for CO_2, H_2O, and NH_3 is zero)

$RQ = f / a$

$Y_{x/s} = c$

$Y_{p/s} = d$

→ determine stoichiometric coefficients (a, b, c, d, e, and f)

Determination of stoichiometric coefficients

- **Eq(4) can lead to**
  - elemental balance on C, H, O, and N
  - available electron balance

$$\gamma_s = 4 + m - 2n$$

$$\gamma_b = 4 + \alpha - 2\beta - 3\delta$$

$$\gamma_p = 4 + x - 2y - 3z$$

Example

For the following biological conversion,

$$100C_6H_{12}O_6 + 11.2NH_3 \rightarrow 13C_aH_bO_cN_d + 56C_4H_{10}O + 22C_3H_6O$$
$$+ 0.4C_4H_8O_2 + 14C_2H_4O_2 + 221CO_2 + 135H_2 + 0.7C_2H_6O$$

(a) Determine the chemical composition of the bacteria (a, b, c, and d).

(b) Determine the degree of reduction of the bacteria.

Example

a) a = 4.46
   b = 16.01
   c = 3.88
   d = 0.86

b) $\gamma = 5.27$

Example 7.1

$$C_{16}H_{34} + aO_2 + bNH_3 \rightarrow c[C_{4.4}H_{7.3}N_{0.86}O_{1.2}] + dH_2O + eCO_2$$

substrate biomass

2/3 of substrate carbon is converted into cell biomass.

(a) Stoichiometric coeff a, b, c, d, e = ?

(b) $Y_{x/s}$, $Y_{x/o2}$ = ?

(a) - g of C converted to cell $= (16)(\quad)(\frac{2}{3}) = c\,(4.4)(\quad)$

$c = 2.42$

- C converted to CO_2 $= 192 - (16)(\quad)(\frac{2}{3}) = e(12)$

$e = 5.33$

- N balance

$b\,(14) = c(0.386)(\quad)$

$b = 2.085$

- H balance

$34 + 3b = 7.3c + 2d$

$d = 11.29$

- O balance : $a = 12.43$

Example 7.1

(b) $Y_{x/s}$, $Y_{x/o2}$ = ?

$$Y_{x/s} = \frac{c\ (\text{biomass M.W.})}{\text{substrate M.W.}} = \frac{2.42\ (91.34)}{226.} = 0.98 \text{ g cell / g substrate}$$

$$Y_{x/o2} = \frac{c\ (\text{biomass M.W.})}{a\ (\text{oxygen M.W.})} = \frac{2.42\ (91.34)}{12.43\ (32)} = 0.56 \text{ g cell / g } O_2$$

Theoretical predictions of yield coeff
(1) Aerobic fermentation

- Cell growth yield per available electron in substrate $= 3.14 \frac{\text{g dw cells}}{\text{electron}}$

- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

  $Y_{x/s} = ?$

  # of available electrons in 1 mol of glucose = 24

$$Y_{x/s} = (3.14 \frac{\text{g dw cells}}{\text{electron}})(24 \frac{\text{electrons}}{\text{1 mol glucose}})$$

$$= 76 \frac{\text{g dw cells}}{\text{1 mol glucose}}$$

$$= (76 \frac{\text{g dw cells}}{\text{1 mol glucose}})(\frac{\text{1 mol glucose}}{\text{180 g glucose}})$$

$$= 0.4 \frac{\text{g dw cells}}{\text{g glucose}}$$

Theoretical predictions of yield coeff
(2) Anaerobic fermentation

- $Y_{X/ATP} = 10.5 \ \frac{\text{g dw cells}}{\text{mol ATP}}$
- $Y_{X/S} = ?$

If N moles of ATP are produced per 1 g substrate consumed

$$Y_{X/S} = Y_{X/ATP} \cdot N$$

$$\frac{\text{g dw cells}}{\text{g substrate}} = \left(\frac{\text{g dw cells}}{\text{mol ATP}}\right)\left(\frac{\text{mol ATP}}{\text{g substrate}}\right)$$

Stoichiometry for cell growth

Yeast cells are growing in a culture medium that contains methanol and ammonia as the only carbon-energy and nitrogen sources, respectively. The cell composition (mass basis) of yeast cell is C 50%, O 25%, H 7%, and N 10%.

If the experimental cell yield was determined to be 0.35 g of cell/g methanol:

(1) What is the oxygen yield coeff. (g O_2/g cell) of the organism?

(2) What is the corresponding respiratory quotient (RQ, mM CO2/mM O2)?

Alcohol Fermentation

Ethanol was produced by batch fermentation of facultative yeasts. The carbon source was glucose.

$$C_6H_{12}O_6 + \text{yeasts} \rightarrow 2C_2H_5OH + \text{more yeasts} + 2CO_2$$

The initial glucose concentration was 200 g/l and the glucose was completely consumed for both cell growth and ethanol production through the fermentation. The final cell concentration was 15 g/l, and $Y_{x/s}$ = 0.5. Calculate the maximum ethanol concentration at the end of the fermentation.