

7. Stoichiometry of Microbial Growth and Product Formation

- 7.1. Introduction
- 7.2. Some Definitions of Yield Coefficients
 - Growth yield and etc.
 - RQ : respiratory quotient
 - Defined as the moles of CO_2 produced per mole of oxygen consumed

7.3. Stoichiometric Calculations

■ 7.3.1. Elemental Balances

One mole of biological materials is defined as the amount containing 1 gram atom of carbon, such as $\text{CH}_\alpha\text{O}_\beta\text{N}_\delta$.

Assumption: No extracellular products other than H_2O and CO_2 are produced.

Elemental Balances



where CH_mO_n : 1 mole of carbohydrate

$\text{CH}_\alpha\text{O}_\beta\text{N}_\delta$: 1 mole of cellular material

Elemental Balances

C:	$1 = c + e$		Eq(2)
H:	$m + 3b = c\alpha + 2d$		
O:	$n + 2a = c\beta + d + 2e$		
N:	$b = c\delta$		
RQ = e/a			Eq(3)

We have five equations and five unknowns (a, b, c, d, e). With a measured value of RQ, these equations can be solved to determine the stoichiometric coefficients.

7.3.2. Degree of Reduction

- Elemental balances provide no insight into the energetics of a reaction.
 - The concept of degree of reduction has been developed and used for proton-electron balances in bioreactions.
- **Degree of reduction (γ)** for organic compounds
 - Defined as the number of equivalents of available electrons per gram atom C.

Degree of Reduction

- Degree of reduction for some key elements

$$C=4, H=1, N =-3, O =-2, P=5, S=6$$

- Calculation of γ

- Methane (CH₄): $1 \times 4 + 4 \times 1 = 8$

$$\gamma = 8/1 = 8$$

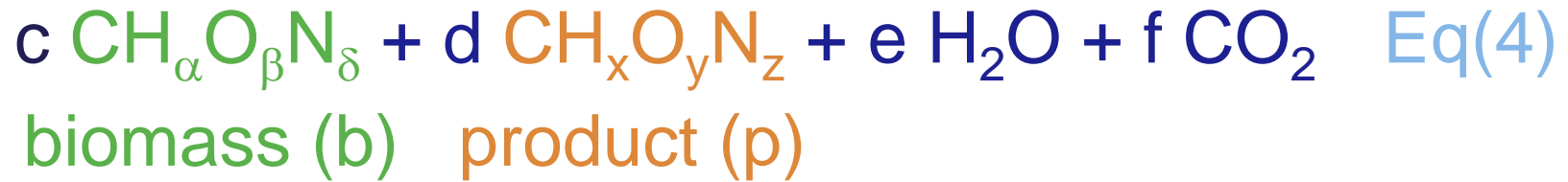
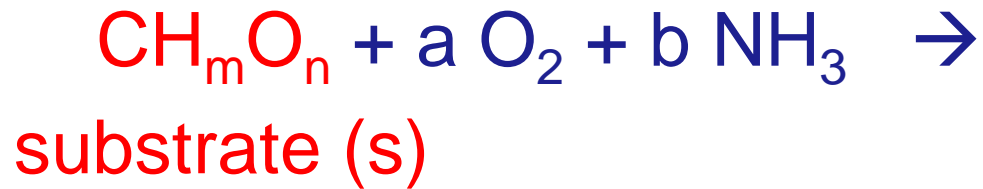
- Glucose (C₆H₁₂O₆): $6 \times 4 + 12 \times 1 + 6 \times (-2) = 24$

$$\gamma = 24/6 = 4$$

- Ethanol (C₂H₅OH): $2 \times 4 + 6 \times 1 + 1 \times (-2) = 12$

$$\gamma = 12/2 = 6$$

Aerobic production of a single extracellular product



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

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

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

$$\text{Eq(5)}$$

For CO_2 , H_2O , and NH_3 , the degree of reduction is zero.

Aerobic production of a single extracellular product

- Eq(4) can lead to
 - elemental balance on C, H, O, and N
 - available electron balance
 - energy balance
 - total mass balance
- Of the equations, only six will be independent.
 - We would typically choose a carbon, a nitrogen, and an available-electron balances.

Balance Equations

C: $c + d + f = 1$ Eq(6)

N: $c \delta + d z = b$ Eq(7)

elec: $c \gamma_b + d \gamma_p = \gamma_s - 4 a$ Eq(8)

$RQ = f / a$ Eq(9)

$Y_{x/s} = c$ Eq(10)

$Y_{p/s} = d$ Eq(11)