BIOREACTOR ENGINEERING
Chapter 7
Stoichiometry of Microbial Growth and Product Formation

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Chapter Description

- Topic Outcomes
  - Describe the importance of stoichiometry in the conversion of substrate into product and cellular material.
  - Perform stoichiometry calculation for the cell growth and product formation.

- References

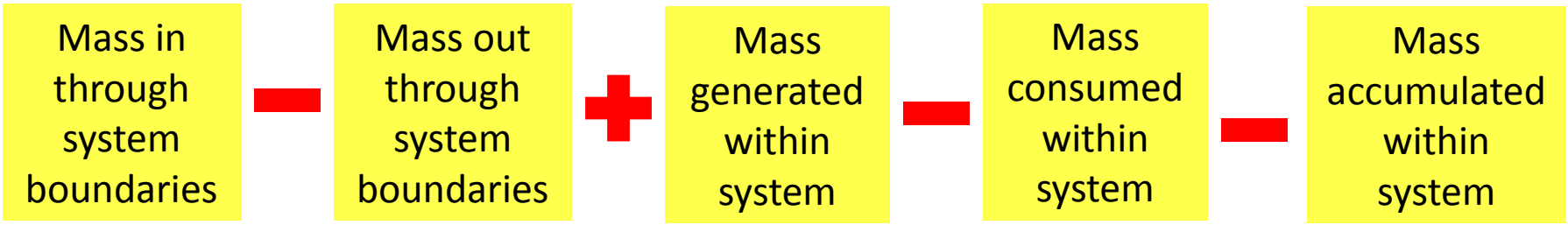
  - Doran, P.M. (2013) Bioprocess Engineering Principles. Elsevier.
  - Liu, S. (2013) Bioprocess Engineering: Kinetics, Biosystem, Sustainability and Reactor Design. Elsevier.
  - Rao, D.G. (2010) Introduction to Biochemical Engineering. McGraw Hill.

Topic Outline

- Introduction
- Stoichiometric Calculation using Elemental Balances

Introduction

- The law of conservation of mass:
  - Mass can neither be created nor destroyed



Introduction

Conversion of substrate, oxygen and nitrogen for cell growth:

$$C_wH_XO_yN_z + a\,O_2 + b\,H_gO_hN_i \rightarrow c\,CH_\alpha O_\beta N_\delta + d\,CO_2 + e\,H_2O$$

If we provide **X kg** substrate, how much cell is produced?

If we provide **X kg** C-source substrate and **Y kg** N-source substrate, when all the C-source substrate is consumed, will there be N-source substrate left in the broth at the end of the culture?

How much oxygen is needed to produce **B kg day^{-1}** of cell?

How much substrate is required to produce **Z tonnes** of product per year?

Introduction

- General stoichiometric equation for cell growth is:

$$C_wH_XO_yN_z + a\,O_2 + b\,H_gO_hN_i \rightarrow c\,CH_\alpha O_\beta N_\delta + d\,CO_2 + e\,H_2O$$

- a, b, c, d, and e are stoichiometric coefficients
- $C_wH_xO_yN_z$ is the C-source, e.g., $C_6H_{12}O_6$ (glucose)
- $H_gO_hN_i$ is the N-source, e.g., NH_3 (ammonia)
- $CH_\alpha O_\beta N_\delta$ is the molecular formula for cell (based on one carbon)
  - why C, H, O, N ?
  - what are the values of α, β and δ ?

Introduction

- Cellular content: 70% is water, the rest is dry matter.
- Thus, the cell composition is expressed on a dry basis.
- 90% – 95% of cell is accounted for by C, H, O and N.
- Cell composition does not vary much.
- General formula: $CH_{1.8}O_{0.5}N_{0.2}$
- MW of cell = 24.6 + ash (5% – 10%)

Introduction

- Exercise 1

Stoichiometric Calculation -Elemental Balances

- a, b, c, d, and e can be determined by elemental balances:
  - C balance: $w = c + d$
  - H balance: $x + bg = c\alpha + 2e$
  - O balance: ?
  - N balance: ?
- We have 5 unknown but 4 balance equation. Therefore,

$$\text{Respiratory quotient (RQ)} = \frac{\text{moles of } CO_2 \text{ formed}}{\text{moles of } O_2 \text{ consumed}}$$

$$RQ = \frac{d}{a}$$

Stoichiometric Calculation -Elemental Balances

- Exercise 2

Stoichiometric Calculation -Elemental Balances

We can now answer

$$C_wH_XO_yN_z + a\,O_2 + b\,H_gO_hN_i \rightarrow c\,CH_\alpha O_\beta N_\delta + d\,CO_2 + e\,H_2O$$

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How much substrate is required to produce **Z tonnes** of product per year?

Stoichiometric Calculation -Elemental Balances

- Exercise 3

CREDITS

Special thanks to
- Prof. Dr. Tey Beng Ti
- Prof. Madya Dr. Rosfarizan binti Mohamad
- Dr. Farhan binti Mohd Said

Thanks to Dr. Rozaimi bin Abu Samah for proofreading the learning contents.