

ABE 580
Exam 1
(Closed Book, Closed Notes)
Friday, February 3, 2006

1. Reading knowledge.

a. Briefly describe what is meant by a Type I fermentation (10 points).

b. Products that are the result of a type I fermentation are (check all that apply) (10 points):

- ethanol
- lactic acid
- insulin
- penicillin

c. Fermentation of glucose to ethanol occurs via the glycolytic pathway (20 points).

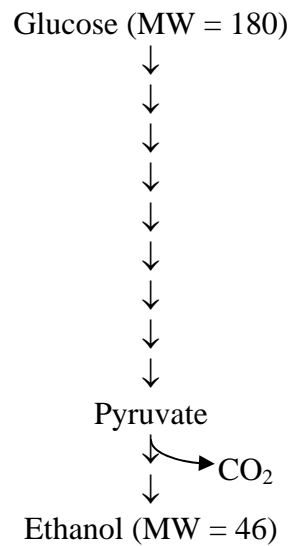


Figure 1.1. Schematic of glycolytic pathway.

i. How many moles of ethanol are produced per mole of glucose?
(15 points)

_____ 1
_____ 2
_____ 3

ii. How many molecules of ATP are produced? (5 points)

_____ 2
_____ 4
_____ 36

iii. What is the theoretical (maximum) yield of ethanol if the fermentation was to start with 100 g/L glucose, and the glucose was completely fermented? (show your work) (5 points)

- d. Convert the equations below into SIMBAS notation showing input (I) and (O) output variables. (10 points)

Equation (1) $\frac{ds}{dt} = -Y_{s/x} \frac{dx}{dt}$

Equation (2) $\frac{dx}{dt} = \left(\frac{\mu_{\max} S}{k_s + S} \right) X$

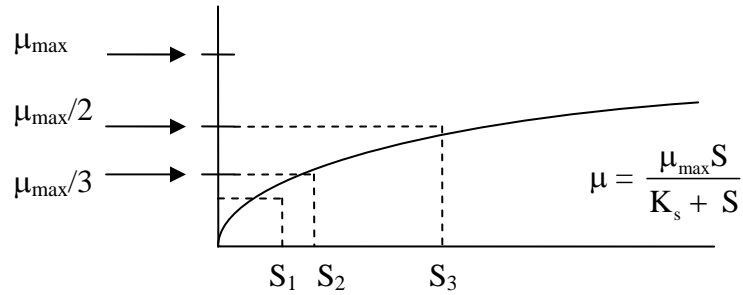
SIMBAS Notation:

Equation (1):

Equation (2):

2. Reading Knowledge.

a.



Identify the substrate concentration that corresponds to K_s . Show your work, and check one answer (10 points):

- S_1
 S_2
 S_3

Check one answer that is most correct.

- b. Yeast is a eukaryote
 prokaryote
 extremophile
- c. *E. coli* is a bacterium
 fungus
 anaerobic

d. Monosodium glutamate is commercially derived through fermentation using (check one):

- Corynebacterium glutamicum*
 E. coli
 Saccharomyces cerevisiae
 Trichoderma reesei

e. New biotechnology refers to (check one):

- manipulation of cells machinery through recombinant DNA techniques
 submerged fermentations using wild type yeast
 biotin deficient mutants for antibiotic production

f. Eucaryotes and prokaryotes are capable of either aerobic or anaerobic metabolism.

Is this statement true or false? true
 false

g. Briefly describe what is meant by

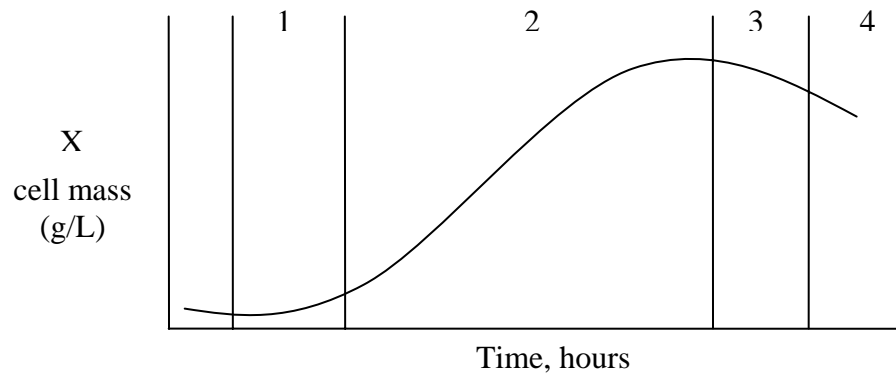
(i) complex media;

(ii) defined media

(i) complex media

(ii) defined media

h. Identify the different growth phases in Figure 2.1.



1. _____

2. _____

3. _____

4. _____

Which phase corresponds to the models that we have developed in class?

3. A well-mixed continuous process for ethanol production is to be carried out for a pure glucose stream derived from hydrolysis of corn starch. The inlet glucose stream is 100 g/L, and is continually metered into a tank containing yeast. The volume of glucose solution added is exactly balanced by the volume of fluid that is removed from the fermentor. Hence, the volume of the fermentation broth is constant. The equations for cell growth and ethanol production are given by:

$$V = V_{\max} \left[\frac{S}{S + K_m} \right] \left[1 - \frac{P}{P_{\max}} \right]^n$$

where

- V = specific ethanol production rate (g ethanol/(g cells • hr))
- V_{\max} = constant = maximum specific ethanol production rate (g ethanol/(g cells • hr))
- K_m = Monod constant
- n = toxic power constant
- P = ethanol concentration (g/L)
- P_{\max} = toxic ethanol concentration

The specific cell growth rate, μ , is given by:

$$\mu = EV$$

where E denotes the efficiency of cell mass production.

The relation between cells produced and substrate utilized is given by a yield coefficient, $Y_{P/S}$ and for cells this is $Y_{X/S}$. The substrate consumed to provide energy for the cells to simply maintain themselves is given by m . The reactor system for this fermentation is given in Figure 3.1.

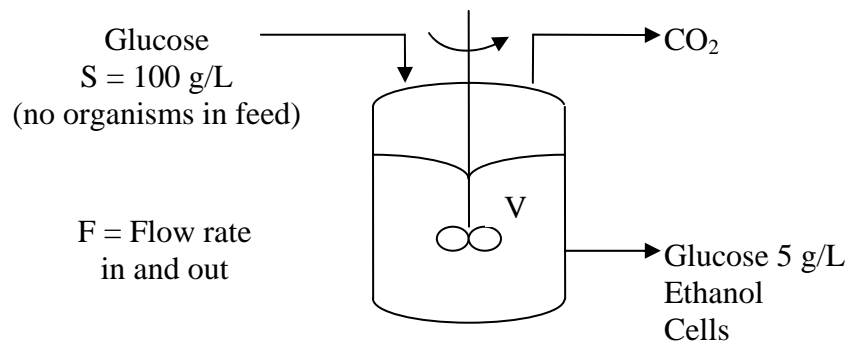


Figure 3.1. Continuous ethanol fermentation.

$Y_{P/S}, Y_{S/X}$	= yield coefficients
F	= flow rate L/hr (this is constant)
V	= volume of media, (this is constant)
m	= maintenance coefficient (g substrate/g cells)

Set up the equations for this type of fermentation system by providing the following equations.

- a. Mass balance equation for cells (10 points).

$$V \frac{dx}{dt} =$$

- b. Mass balance for substrate including cells (be sure to include term for cell maintenance) (10 points).

$$V \frac{ds}{dt} =$$

- c. Express equations in (a) and (b) in terms of the dilution rate $D (= F/V)$ (10 points).

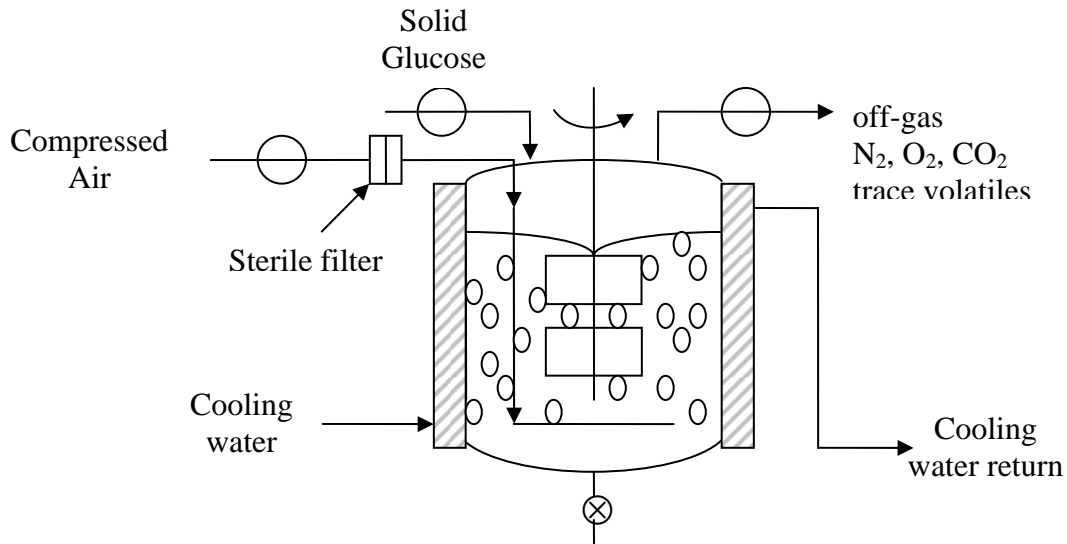
$$\frac{dx}{dt} =$$

$$\frac{ds}{dt} =$$

d. What is the specific growth rate at steady state? (Show your work) (10 points).

e. What is the expression for substrate concentration at steady state (i.e., for a fixed value of D)? (Show your work) (10 points).

4. A research fermentor with a design volume of 20 L, and a working volume, V , of 15 L is to be used to measure the effect of dissolved oxygen concentrations on cell growth of a bacterial microorganism. The fermentor, shown in the schematic diagram below, represents a fed batch system in which the carbon source, glucose, is fed as a solid into the fermentation vessel, so that the concentration of the glucose is kept constant. Nothing is removed during the course of the fermentation except off-gas consisting of CO_2 , N_2 , O_2 , and small amounts of volatile organic compounds. Given the parameters below, set up a system of differential equations that represents a model of this type of fermentation. This model gives changes in cell mass, product, and dissolved oxygen as a function of time, as well as the amount of (solid) glucose that is added to the fermentor as a function of time.



Cell growth generates CO_2 , heat, and product (P) as well as cell mass, X . The governing relations, determined by experiment are:

Specific growth rate of cells:

$$\mu = \mu_{\max} \left(\frac{C_{\text{DO}}}{K_L + C_{\text{DO}}} \right) \quad (4.1)$$

where

C_{DO} = dissolved oxygen, g/L

Constants:

K_L = growth constant, (g/L)

μ_{\max} = maximum specific growth rate, g/(L • hr)

Yield coefficients:

$$\begin{aligned} Y_{DO/X} &= \text{yield coefficient for cells based on dissolved oxygen} \\ &= \frac{\Delta C_{DO}}{\Delta X} \frac{\text{g/L}}{\text{g/L}} \end{aligned}$$

$$\begin{aligned} Y_{P/X} &= \text{yield coefficient for product relative to cell mass generated} \\ &= \frac{\Delta p}{\Delta x} \frac{\text{g/L}}{\text{g/L}} \end{aligned}$$

$$Y_{G/X} = \frac{\Delta G}{\Delta X} \bullet \frac{\text{g glucose}}{\text{g cell mass}}$$

$$Y_{H/DO} = \frac{\Delta H}{\Delta C_{DO}} \frac{\text{calories}}{\text{g oxygen}}$$

Oxygen transfer equation:

$$\frac{dC_{DO}}{dt} = k_L a (C_{DO}^* - C_{DO}) \quad (4.2)$$

where

$$\begin{aligned} C_{DO} &= \text{average dissolved oxygen g/L} \\ C_{DO}^* &= \text{equilibrium (saturation) concentration of dissolved oxygen, g/L} \\ k_L &= \text{mass transfer coefficient g/(cm} \bullet \text{ hr)} \\ a &= \text{interfacial area cm}^2\text{/cm}^3 \\ V &= \text{volume of fermentation media, L} \end{aligned}$$

Set up the model by answering the questions or giving the indicated equations.

- a. Is it appropriate to assume the specific growth rate is constant with respect to C_{DO} ? Why or why not (briefly explain) (10 points).

_____ Yes _____ No (Check one)

Rationale:

- b. Equation for cell mass (10 points):

$$\frac{dx}{dt} =$$

- c. Equation for product concentration (10 points):

$$\frac{dp}{dt} =$$

- d. Equation for glucose added (10 points):

$$\frac{dG}{dt} =$$

e. Equation for dissolved oxygen consumed (10 points):

$$\frac{dC_{ox}}{dt} =$$

f. Equation for heat, H, generated (10 points):

$$\frac{dH}{dt} =$$