

**COLLEGE OF ENGINEERING
CHEMICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**

BINDER REPORT COVER PAGE

**CHEG 4315 – P01
Bioengineering**

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Dr. Jorge Gabitto

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 4315 P01 - Bioengineering
SPRING 2022**

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Course Description in ABET Format

CHEMICAL ENGINEERING DEPARTMENT CHEG 4315 Bioengineering

1.	Course number and name:	CHEG 4315 Bioengineering
2.	Credits and contact hours:	3 credit hours; 3 contact hours
3.	Instructor's or course coordinator's name:	Dr. Jorge F. Gabitto
4.	Text book: Title:	"Biochemical Engineering Fundamentals"
	Author:	J. E. Bailey, and D. F. Ollis
	Publisher, Year & Edition:	McGraw-Hill, New York, 1986 or newer.
	a. Other Supplemental material	"Fundamentals of Biochemical Engineering", first edition, R. Dutta, download from: https://www.pdfdrive.com/fundamentals-of-biochemical-engineering-e5610684.html , 2008
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	(3-0) Credit 3 semester hours. Design and analysis of biochemical systems with applications in biomedical engineering and metabolic processes, enzyme catalyzed reactions and product separation, biomass production, and wastewater treatment. Emphasis is placed upon the application of biochemical systems structure, reaction kinetics, transport processes, and control in the design and use of biochemical reactors and separation units.
	b. Prerequisites or Co-requisites	Senior standing in the Chemical Engineering major.
	c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Selected elective.
6.	Specific goals for the course	Students will be able to :
	Specific learning outcomes	a. Design biological industrial processes b. Design biological separation processes c. Design biological industrial control systems
	Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.	This course addresses: Outcome 1 An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. Outcome 2 An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health,

		safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
7	Brief list of topics to be covered	Topic 1 Chemicals of life (lectures) Topic 2 Basic microbiology (Lectures) Topic 3 Kinetics of enzyme catalyzed reactions (Lectures) Topic 4 Applied enzyme catalysis (Lectures) Topic 5 Bioreactor design (Lectures) Topic 6 Transport phenomena in biological systems (Lectures) Topic 7 Sterilization (Lectures) Topic 8 Final and Three partial exams

***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group.

End of Semester Course Assessment Reports Spring 2022 and Last Two Assessment Periods.

Each summary contains the following information.

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

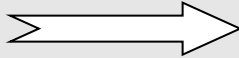
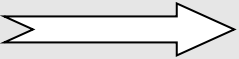
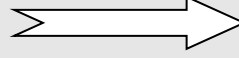
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

Table 2.1. END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG4315-P01 Bioengineering
Spring 2022 SEMESTER

Report Prepared by: Dr. Jorge Gabitto

Report Date: May 20, 2022

Semester	Analysis Type	Number of Students	Outcome 1 Ability to design and conduct experiments.			Outcome 2 Oral & Written Communication		
			Expected Average	Class Average	% Students Meeting Expected Average	Expected Average	Class Average	% Students Meeting Expected Average
Spring 2022	Direct	15	75	81.4	75.0	75	75.2	73.3
Spring 2021	Direct	13	75	73.3	85.0	75	71.4	85.0
Spring 2020	Direct	20	75	85.4	90	75	89.3	100.0
Implementation Summary			Practice sessions in problem solving and biology.			Special problems to show design problems and societal concerns.		
Perceived Problems			Students have problems applying normal engineering principles to biological problems. This issue leads to wrong conclusions.			Students have problems applying design principles to biological problems due to lack of familiarity with multi-phase systems.		
Plans for Addressing Problems			The following is recommended for implementation next course offering: 1. Stress on chemistry and biology concepts. 2. Identification between basic engineering and biological systems. 3. Stressing similarities between enzyme and catalytic reactions.			The instructor did: 1. Show similarities between bio and normal industrial reactors. 2. Instructor should present design cases for class discussion 3. Ethical and societal issues should also be discussed in class		
Overall Trend over Periods			The class average has increased significantly over last semester. The compliance percentage has decreased though. Still more work is needed. Extra data are needed to figure it out if it is due to the pandemic or a trend.			The class average has increased over last semester. The compliance percentage has decreased though. Still more work is needed. Extra data are needed to figure it out if it is due to the pandemic or a trend.		

Grades Sheet Showing Student and Class Performance in Outcomes

Grade Sheet Showing Student and Class Performance in Course Outcomes

CHEG 4315-P01 SPRING 2022 SEMESTER

	HW1	HW 2	Test 1	HW 3	HW 4	Test 2	test 3	Final	Outcome 1 Problem solving	Outcome 2 Engineering Design
Student 1	10	9.7	8.5	7.5	7.5	9	9	10	8.75	8.25
Student 2	9.3	7	7	6.75	6.5	9	7	7	7	7.875
Student 3	9.6	8.7	7.7	7.5	7	8	9	8.5	8.35	7.75
Student 4	9	9.7	10	6.35	5.5	6.5	7.5	6	8.75	6.425
Student 5	9	5.4	8	9	1	8.5	8	7.5	8	8.75
Student 6	9	8.8	8.5	5.5	6.8	5	8.5	8	8.5	5.25
Student 7	9.5	7.2	10	9.5	5.5	9	7	9.5	8.5	9.25
Student 8	7.7	8.7	5.5	3	5.3	5.5	7.5	7.5	6.5	4.25
Student 9	9.5	9.1	7.5	7	1	6	6	7.5	6.75	6.5
Student 10	10	10	10	10	6.8	9	10	7	10	9.5
Student 11	10	10	10	10	8.5	9	10	9.5	10	9.5
Student 12	8.5	6	8	4.5	10	7	7.5	8.8	7.75	5.75
Student 13	8	7.1	6.5	6	7.5	8	7	9.5	6.75	7
Student 14	8.3	6	9	5	7	8.5	6		7.5	6.75
Student 15	10	8.4	10	10	9	10	8		9	10
									122.1	112.8
									8.41 (73.3%)	7.52 (66.3%)

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Homework 1

TOPICS COVERED IN Homework 1

1. Chemicals of Life

**BIOENGINEERING
SPRING 2022**

Homework Questions and Solution for Homework 1

CHEG 4315
Homework 1

1). Write the generic formula for a monosaccharides (simple sugar). Same for glucose.

Ans.: $C_n(H_2O)_m$

2). Monosaccharides present two kind of cyclic structures. How many atoms does the cycle have?

Ans.: a) Piranose with 5 C and 1 O and b) Furanose with 4 C and 1 O.

3). Which are the components of cellulose?

Ans.: Cellulose is a polysaccharide consisting of a linear chain of several hundred to many thousands of β linked D-glucose units

4). Which are the main components of fats?

Ans.: Fats are a subgroup of lipids called triglycerides. Triglycerides are esters of glycerol and fatty acids (long chain organic acids).

5). Which are the functions of lipids?

Ans.: The functions of lipids include storing energy, signaling, and acting as structural components of cell membranes.

6). Which are the main functional groups of amino acids?

Ans.: Amino acids are organic compounds containing amine ($-NH_2$) and carboxyl ($-COOH$) groups, along with a side chain (R group) specific to each amino acid.

7). How do you define a protein?

Ans.: Proteins are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. Proteins perform a vast array of functions within organisms, including catalysing metabolic reactions, DNA replication, responding to stimuli, providing structure to cells and organisms, and transporting molecules from one location to another. Proteins differ from one another primarily in their sequence of amino acids.

8) Which kind of bonds link amino acids together?

Ans.: The different amino acids are linked by bonds between the amino group of one amino acid with the carboxyl group of another, resulting in a linear structure called peptide.

9). How many structures proteins have?

Ans.: Biochemists often refer to four distinct aspects of a protein's structure:

- *Primary structure*: the amino acid sequence. A protein is a polyamide.
- *Secondary structure*: regularly repeating local structures stabilized by hydrogen bonds. The most common examples are the α -helix, β -sheet and turns. Because secondary structures are local, many regions of different secondary structure can be present in the same protein molecule.
- *Tertiary structure*: the overall shape of a single protein molecule; the spatial relationship of the secondary structures to one another. Tertiary structure is generally stabilized by nonlocal interactions, most commonly the formation of a hydrophobic core, but also through salt bridges, hydrogen bonds, disulfide bonds, and even posttranslational modifications. The term "tertiary structure" is often used as synonymous with the term *fold*. The tertiary structure is what controls the basic function of the protein.
- *Quaternary structure*: the structure formed by several protein molecules (polypeptide chains), usually called *protein subunits* in this context, which function as a single protein complex.

10). Which are the main components of RNA? Same for DNA

Ans.: Ribonucleic acid (RNA) and Deoxyribonucleic acid (DNA) are polymeric molecules essential in various biological roles in coding, decoding, regulation and expression of genes. RNA and DNA are nucleic acids made up of three components: a ribose sugar; a nitrogen base, adenine (A), cytosine (C), guanine (G), thymine (T) or uracil (U); and a phosphate group attached to the 3' position of one ribose and the 5' position of the next.

11). Which are the attractive pairs of nitrogen bases in RNA? Same for DNA.

Ans.: In RNA, A-U and C-G. In DNA, A-T and C-G.

ABOVE AVERAGE

CHEG-4315

Professor Dr. Jorge F. Gabitto

Name: Nina Patthammavong

Homework 1

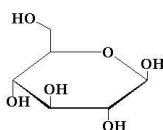
1) Write the generic formula for a monosaccharide (simple sugar). Same for glucose.

⇒ The formula for a monosaccharide is $C_nH_{2n}O_n$

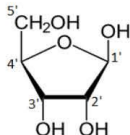
2) Monosaccharides present two kinds of cyclic structures. How many atoms do the cycle have?

⇒ There are two kinds of cyclic structures, including

- Pyranose has 5 carbons and 1 oxygen



- Furanose has 4 carbons and 1 oxygen



3) Which are the components of cellulose?

⇒ Cellulose is a polysaccharide which consists of a linear chain of several hundred to many thousands of β linked D-glucose units.

4) Which are the main components of fats?

⇒ Fats are a subgroup of lipids called triglycerides. Triglycerides are ester of glycerol and fatty acids.

5) Which are the functions of lipids?

⇒ The function of lipids includes storing energy, signaling, and acting as structural components of cell membrane.

6) Which are the main functional groups of amino acid?

⇒ The main functional groups of amino acids are amine (-NH_2) and carboxyl group (-COOH) along with a side chain R-group.

7) How do you define a protein?

⇒ Proteins are large, complex molecules that are made up of hundreds or thousands of smaller units of amino acids. Proteins perform a vast array of functions within organisms, including catalyzing, metabolic reactions, DNA replication, responding to stimuli, providing structure to cells and organisms, and transporting molecules from one location to another. Proteins differ from one another primarily in their sequence of amino acids.

8) Which kind of bond link amino acids together?

⇒ The bond that holds together the two amino acids is a peptide bond.

9) How many structures proteins have?

⇒ There are four structures of protein

- **Primary structure:** is the sequence of amino acids held together by peptide bonds.
- **Secondary structure:** is the protein beginning to fold up. It can have two types of structure, including the alpha helix and beta pleated sheet which held by hydrogen bonds.
- **Tertiary structure:** is the protein folded into its precise 3D structure, relating to the function. This is held together by a range of non-covalent interactions

between side groups, including ionic interactions, disulfide bridges, hydrophobic interactions, Van der Waals forces and hydrogen bonds.

- **Quaternary structure:** is a protein that refers to those macromolecules with multiple polypeptide chains or subunits.

10) Which are the main components of RNA? Same for DNA

⇒ Both DNA and RNA are made from nucleotides. Each contains a ribose sugar, nitrogen base, including adenine (A), cytosine (C), uracil (U), guanine (G), or thymine (T), and a phosphate group attached to the 3' position of one ribose and the 5' position of the next.

11) Which are the attractive pairs of nitrogen bases in RNA? Same for DNA.

- In RNA: A-U and G-C
- In DNA: T-A and G-C

AVERAGE

Davin Duraway

CHEG 4153

Homework 1

1. Can Han On ; $C_6H_{12}O_6$

2. 5 or 6 atoms

3. Carbon, Hydrogen, & Oxygen

4. Glycerol & Fatty acids

5. energy reserve, hormone regulators, chemical messengers, cushion organs, transport nutrients.

6. amine (NH_2) and carboxylic acid ($COOH$)

7. Naturally occurring, extremely complex substance consisting of amino acid residues joined by peptide bonds.

8. Peptide Bonds

9. Four

10. RNA - Ribose, Phosphate group, Nitrogen Base

DNA - Deoxyribose, phosphate group, Nitrogen Base

11. RNA

A-U
G-C

DNA

A-T
G-C

BELOW AVERAGE

1.) $C_n(H_2O)_m$ - Sugar ✓ 8

glucose - $C_6H_{12}O_6$

2.) - .75 ✓

3.) The main component of cellulose is glucose

4.) Main components of fats are triglycerides - .5

5. Lipids functions are storing energy and acting as the main components of cell membrane

6. amino acids main function groups are Carboxylic acid ($COOH$) and NH_2 ✓

7. Proteins are biomolecules consisting of one or more chains of amino acid residues. ✓

8. The bonds between two amino acids is called peptide bonds. ✓

9. There are four: Primary, Secondary, Tertiary, and Quaternary ✓ - .75

10.

II. RNA

A-U C-G

DNA

A-T C-G ✓

BIOENGINEERING

SPRING 2022

Title of Assignment: Homework 2

TOPICS COVERED IN Homework 2

2. Kinetics of Enzymatic Reactions

**BIOENGINEERING
SPRING 2022**

Homework Questions and Solution for Homework 2

CHEG 4315

HW 2

1). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

2). Assume that the following sequence describes the reactions of two different substrates is catalyzed by one enzyme:



a). Derive the kinetic equation using the Michealis-Menten procedure.

b). Simplify the rate equation if $S_1 \gg S_2$.

3). Derive the rate equation for competitive inhibition. Use:



4). Derive the rate equation for competitive self-inhibition. Use:



5). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.03 \text{ mol L}^{-1}, v_{\max} = 13 \text{ mol L}^{-1} \text{ min}^{-1}$$

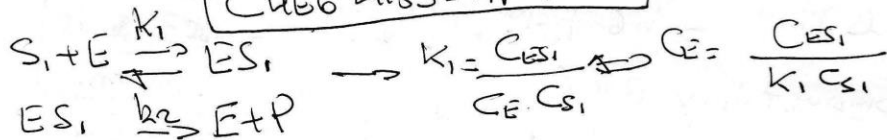
Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

6). A substrate is converted to a product by the catalytic action of an enzyme. The slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$) are:

$$\text{Slope} = 0.001, \text{ intercept} = 0.1.$$

Calculate the Michaelis-Menten kinetic parameters (K_M and $v_{\max}$) for this enzyme reaction. Justify.

1)

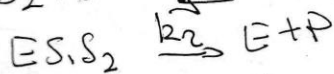
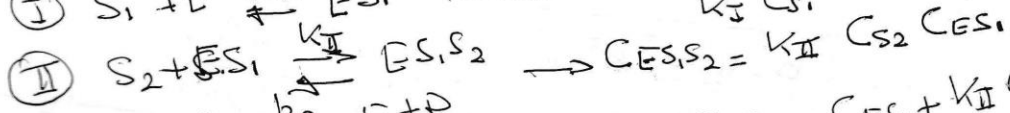


$$C_E^0 = C_E + C_{ES_1}, \quad C_E^0 = \frac{C_{ES_1}}{k_1 C_{S_1}} + C_{ES_1}$$

$$r_p = k_2 C_{ES_1} = \frac{k_2 C_E^0 k_1 C_{S_1}}{1 + k_1 C_{S_1}} \rightarrow r_p = \frac{r_{max} C_{S_1}}{K_M + C_{S_1}}$$

$r_{max} = k_2 C_E^0$

2)



$$C_E^0 = C_E + C_{ES_1} + C_{ES_1 S_2} = \frac{C_{ES_1}}{k_1 C_{S_1}} + C_{ES_1} + K_{II} C_{S_2} C_E$$

$$r_p = C_{ES_1 S_2} \times k_3$$

$$\text{Use } K_{II} = \frac{C_{ES_1 S_2}}{C_{ES_1} C_{S_2}} \rightarrow C_{ES_1} = \frac{C_{ES_1 S_2}}{K_{II} C_{S_2}}$$

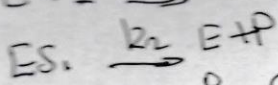
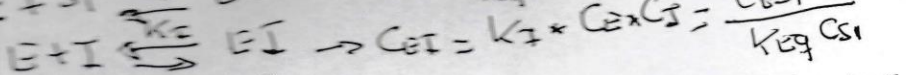
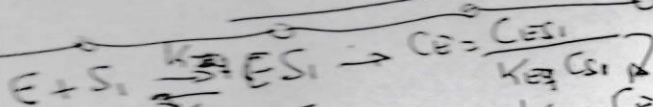
REPLACING IN $\textcircled{I}$

$$C_E^0 = \frac{C_{ES_1 S_2}}{K_{II} C_{S_2}} + \frac{C_{ES_1 S_2}}{K_{II} C_{S_2}} + C_{ES_1 S_2} \quad \left| \quad C_E = \frac{C_{ES_1}}{k_1 C_{S_1}} = \frac{C_{ES_1 S_2}}{K_{II} k_1 C_{S_1} C_{S_2}} \right|$$

$$r_p = k_3 C_{ES_1 S_2} = \frac{r_{max} C_{S_1} C_{S_2}}{1 + K_{II} C_{S_1} + K_{II} k_1 C_{S_1} C_{S_2}}$$

$$\therefore r_p = k_3 C_{ES_1 S_2} = \frac{r_{max} C_{S_1} C_{S_2}}{1 + K_{II} C_{S_1} + K_{II} k_1 C_{S_1} C_{S_2}}$$

3)



$$C_E^0 = C_E + C_{ES_1} + C_{EI} = \frac{C_{ES_1}}{k_1 C_{S_1}} + C_{ES_1} + \frac{K_I C_I C_{ES_1}}{k_1 C_{S_1}}$$

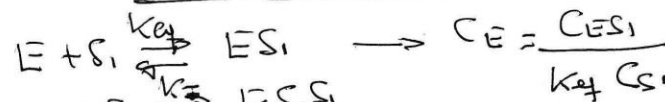
REPLACING IN

$$\text{OR } r_p = k_3 C_{ES_1} = \frac{r_{max} C_{S_1}}{1 + K_I C_I + K_I k_1 C_I C_{S_1}}$$

4)

CHEG W153 - HW 2

P.2



$$C_{ES_1 S_1} = k_2 C_{S_1} C_{ES_1}$$

$$C_{ES_1} = k_1 C_{S_1} C_{ES_1}$$

$$C_E^0 = C_E + C_{ES_1} + C_{ES_1 S_1} = \frac{C_{ES_1}}{k_1 C_{S_1}} + C_{ES_1} + k_2 C_{S_1} C_{ES_1}$$

$$r_P = k_2 C_{ES_1} = \frac{k_2 C_E^0 k_1 C_{S_1}}{(1 + k_1 C_{S_1} + k_1 k_2 C_{S_1}^2)}$$

5) JUSTIFICATION FOR PROBLEMS 5) AND 6)

$$r = \frac{r_{max} C_S}{K_M + C_S} \quad \text{REVERSE}$$

$$\frac{1}{r} = \frac{K_M + C_S}{r_{max} C_S} = \frac{K_M}{r_{max} C_S} + \frac{1}{r_{max}}$$

IF PLOT $\frac{1}{r}$ vs $\frac{1}{C_S} \Rightarrow \frac{K_M}{r_{max}} = \text{SLOPE}$

$$\text{SLOPE} = \frac{0.03 \frac{\text{MOL}}{\text{L}} \cdot \frac{\text{MIN}}{\text{MOL}}}{1.3} = 0.023 \text{ MIN.}$$

 $\frac{1}{r_{max}} = \text{INTERCEPT}$

$$\frac{1}{r_{max}} = \frac{1}{1.3 \text{ MOL}} = 0.77 \text{ L} \cdot \text{MIN} / \text{MOL}$$

6) FROM BEFORE:

$$\frac{1}{r_{max}} = \text{INT.}$$

$$r_{max} = \frac{1}{\text{INT.}} = \frac{1}{0.1} = 10 \frac{\text{L} \cdot \text{MIN.}}{\text{MOL}}$$

$$\text{SLOPE} = \frac{K_M}{r_{max}} \Rightarrow K_M = \text{SLOPE} \times r_{max}$$

$$K_M = 0.001 \text{ MIN.} \times 10 \frac{\text{MOL}}{\text{L} \cdot \text{MIN.}} = 0.01 \frac{\text{MOL}}{\text{L}}$$

$$K_M = 0.01 \frac{\text{MOL}}{\text{L}}$$

USE $\rightarrow$ UNITS = $\frac{\text{MOL}}{\text{L} \cdot \text{MIN.}}$

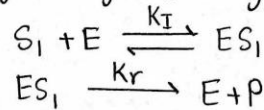
$$r_{max} = 10 \frac{\text{MOL}}{\text{L} \cdot \text{MIN.}}$$

ABOVE AVERAGE

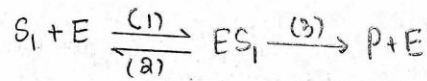
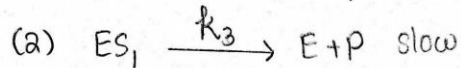
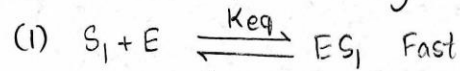
Name: Vivian Patthammavong

10

1. Assume that the following sequence describe the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure:



(1) Fast: $K_{eq} = \frac{C_{ES_1}}{C_{S_1} \cdot C_E}$

$$\Rightarrow C_E = \frac{C_{ES_1}}{K_{eq} \cdot C_{S_1}}$$

(2) slow: $r_p = -r_{S_1} = k_3 C_{ES_1}$

From Enzyme balance

$$C_{E_0} = C_E + C_{ES_1}$$

$$= \frac{C_{ES_1}}{K_{eq} \cdot C_{S_1}} + C_{ES_1}$$

$$= C_{ES_1} \left[\frac{1}{K_{eq} \cdot C_{S_1}} + 1 \right]$$

$$C_{E_0} = C_{ES_1} \left[\frac{1 + K_{eq} C_{S_1}}{K_{eq} \cdot C_{S_1}} \right]$$

$$C_{ES_1} = \frac{C_{E_0} K_{eq} C_{S_1}}{1 + K_{eq} C_{S_1}}$$

we know that

$$r_p = k_3 C_{ES_1}$$

$$= k_3 \left(\frac{C_{E_0} K_{eq} C_{S_1}}{1 + K_{eq} C_{S_1}} \right)$$

$$= \frac{k_3 C_{E_0} C_{S_1}}{1 + K_{eq} C_{S_1}}$$

$$r_p = \frac{k_3 C_{E_0} C_{S_1}}{\frac{1}{K_{eq}} + C_{S_1}}$$

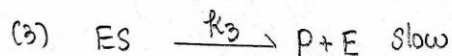
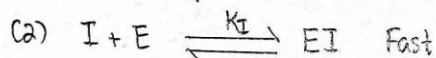
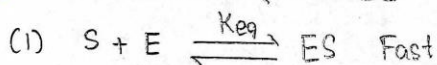
$$r_p = \frac{V_{max} C_{S_1}}{K_M + C_{S_1}}$$

$$C_{ES_1} = \frac{C_{E_0} K_{eq} C_{S_1}}{1 + K_{eq} C_{S_1}}$$

$$k_3 C_{E_0} = V_{max}$$

$$\frac{1}{K_{eq}} = K_M$$

2. Derive the rate equation for competitive inhibition. Use:



$$\text{From (1): } K_{eq} = \frac{C_{ES}}{C_E \cdot C_S} \Rightarrow C_E = \frac{C_{ES}}{K_{eq} C_S}$$

$$\text{From (2): } K_I = \frac{C_{EI}}{C_I \cdot C_E} \Rightarrow C_{EI} = K_I C_I C_E$$

$$\text{From (3) slow: } r_p = -r_s = k_3 C_{ES}$$

⇒ from enzyme balance:

$$C_{E_0} = C_E + C_{ES} + C_{EI}$$

$$= \frac{C_{ES}}{K_{eq} C_S} + C_{ES} + K_I C_I C_E$$

$$= \frac{C_{ES}}{K_{eq} C_S} + C_{ES} + K_I C_I \left(\frac{C_{ES}}{K_{eq} C_S} \right)$$

$$C_{E0} = C_{ES} \left[\frac{1}{K_{eq} C_S} + 1 + \frac{K_I C_I}{K_{eq} C_S} \right]$$

$$C_{E0} = C_{ES} \left[\frac{1 + K_{eq} C_S + K_I C_I}{K_{eq} C_S} \right]$$

$$\Rightarrow C_{ES} = \frac{C_{E0} K_{eq} C_S}{1 + K_{eq} C_S + K_I C_I}$$

we know : $r_p = k_3 C_{ES}$

$$= k_3 \left[\frac{C_{E0} K_{eq} C_S}{1 + K_{eq} C_S + K_I C_I} \right]$$

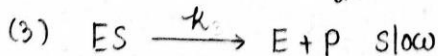
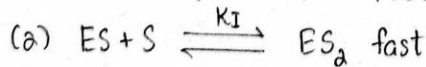
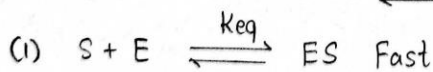
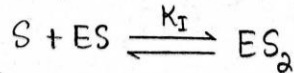
$$= \frac{k_3 C_{E0} C_S}{\frac{1 + K_{eq} C_S + K_I C_I}{K_{eq}}}$$

$$= \frac{k_3 C_{E0} C_S}{\frac{1}{K_{eq}} + C_S + \frac{K_I C_I}{K_{eq}}}$$

$$r_p = \frac{V_{max} C_S}{K_M + C_S + K_I C_I K_M}$$

$$\begin{aligned} k_3 C_{E0} &= V_{max} \\ \frac{1}{K_{eq}} &= K_M \end{aligned}$$

3.1 Derive the rate equation for competitive self-inhibition. Use:



$$\text{from (1) Fast: } K_{eq} = \frac{C_{ES}}{C_S \cdot C_E} \Rightarrow C_E = \frac{C_{ES}}{K_{eq} \cdot C_S}$$

$$\text{from (2) fast: } K_I = \frac{C_{ES_2}}{C_{ES} \cdot C_S} \Rightarrow C_{ES_2} = K_I \cdot C_{ES} \cdot C_S$$

$$\text{from (3) slow: } r_p = -r_s = k C_{ES}$$

Enzym balance: $C_{E0} = C_E + C_{ES} + C_{ES2}$

$$C_{E0} = \frac{C_{ES}}{K_{eq} \cdot C_S} + C_{ES} + K_I C_{ES} C_S$$

$$= C_{ES} \left[\frac{1}{K_{eq} \cdot C_S} + 1 + K_I C_S \right]$$

$$C_{E0} = C_{ES} \left[\frac{1 + K_{eq} C_S + K_{eq} K_I C_S^2}{K_{eq} C_S} \right]$$

$$\Rightarrow C_{ES} = \frac{C_{E0} K_{eq} C_S}{1 + K_{eq} C_S + K_{eq} K_I C_S^2}$$

$r_p = k C_{ES}$

$$= k \left(\frac{C_{E0} K_{eq} C_S}{1 + K_{eq} C_S + K_{eq} K_I C_S^2} \right)$$

$$= k \left[\frac{C_{E0} C_S}{\frac{1 + K_{eq} C_S + K_{eq} K_I C_S^2}{K_{eq}}} \right]$$

$$= \frac{k C_{E0} C_S}{\frac{1}{K_{eq}} + C_S + K_I C_S^2}$$

$$r_p = \frac{k C_{E0} C_S}{K_M + C_S + K_I C_S^2}$$

$$k C_{E0} = v_{max}$$

$$\frac{1}{K_{eq}} = K_M$$

4. A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.03 \text{ mol/L}; \quad V_{\max} = 13 \text{ mol/Lmin}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify

Equation slope: $y = mx + b$

we know: $K_M = 0.03 \text{ mol/L}$

$$V_{\max} = 13 \text{ mol/Lmin}$$

find slope and intercept?

$$r_p = \frac{V_{\max} C_s}{K_M + C_s}$$

$$\frac{1}{r_p} = \frac{K_M + C_s}{V_{\max} C_s}$$

$$= \frac{K_M}{V_{\max} C_s} + \frac{C_s}{V_{\max} C_s}$$

$$= \frac{K_M}{V_{\max} C_s} + \frac{1}{V_{\max}}$$

$$\frac{1}{r_p} = \frac{K_M}{V_{\max}} \cdot \frac{1}{C_s} + \frac{1}{V_{\max}}$$

find slope?

$$\text{slope} = m = \frac{K_M}{V_{\max}} = \frac{0.03 \text{ mol/L}}{13 \text{ mol/Lmin}} = 0.0023 \text{ min}$$

$$m = 2.3 \times 10^{-3} \text{ min} //$$

find intercept?

$$\text{intercept} = b = \frac{1}{V_{\max}} = \frac{1}{13 \text{ mol/Lmin}} = 0.77 \text{ Lmin/mol}$$

$$\text{intercept} = b = 0.77 \text{ Lmin/mol} //$$

5. A substrate is converted to a product by the catalytic action of an enzyme. The slope and the intercept of a Lineweaver-Burk ($1/r$ vs $1/c_s$) are:

$$\text{slope} = 0.001, \text{ intercept} = 0.1$$

calculate the Michaelis-Menten kinetic parameters (K_M and $v_{\max}$) for this enzyme reaction. Justify.

$$\text{given slope} = 0.001 \\ \text{intercept} = 0.1$$

find $v_{\max}$ and K_M = ?

① $v_{\max} = ?$

$$\text{intercept} = \frac{1}{v_{\max}}$$

$$\Rightarrow v_{\max} = \frac{1}{\text{intercept}} = \frac{1}{0.1}$$

$$v_{\max} = 10 \text{ mol/L} \cdot \text{min} //$$

② $K_M = ?$

$$\text{slope} = \frac{K_M}{v_{\max}}$$

$$\Rightarrow K_M = v_{\max} \times \text{slope}$$

$$= (10 \text{ mol/L} \cdot \text{min})(0.001 \text{ min})$$

$$K_M = 0.01 \text{ mol/L} //$$

we have

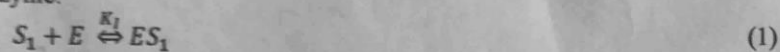
$$\frac{1}{r_p} = \frac{K_M}{v_{\max}} \cdot \frac{1}{c_s} + \frac{1}{v_{\max}}$$

AVERAGE

CHEG 4153

Quiz 1 A

1). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

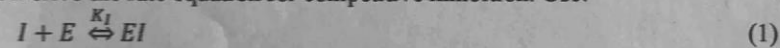
2). Assume that the following sequence describes the reactions of two different substrates is catalyzed by one enzyme:



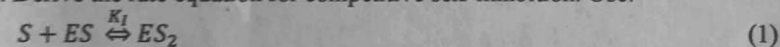
a). Derive the kinetic equation using the Michealis-Menten procedure.

b). Simplify the rate equation if $S_1 \gg S_2$.

3). Derive the rate equation for competitive inhibition. Use:



4). Derive the rate equation for competitive self-inhibition. Use:



5). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.03 \text{ mol L}^{-1}, v_{\max} = 13 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

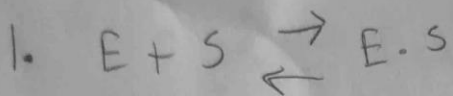
6). A substrate is converted to a product by the catalytic action of an enzyme. The slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$) are:

$$\text{Slope} = 0.001, \text{ intercept} = 0.1.$$

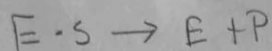
Calculate the Michaelis-Menten kinetic parameters (K_M and $v_{\max}$) for this enzyme reaction. Justify.

Homework #2

Nicholas
McKnight



quasi-equilibrium



rds

$$K_M = \frac{[E][S]}{[E \cdot S]}$$

$$r_p = k[E \cdot S] = \frac{k[E_T] v_{max}}{\left(1 + \frac{K_M}{[S]}\right)}$$

$$[E_T] = [E] + [E \cdot S]$$

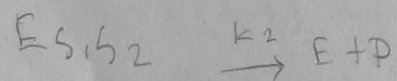
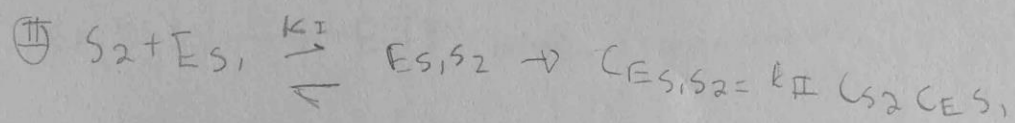
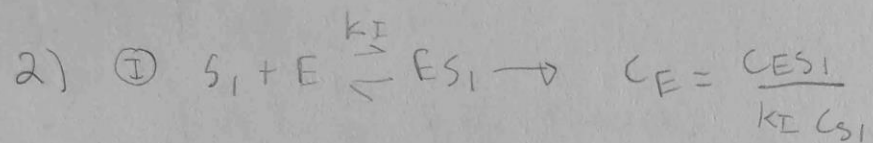
$$r_p = \frac{v_{max}[S]}{([S] + K_M)} \quad \begin{matrix} \text{low } [S] \\ \text{high } [S] \end{matrix}$$

$$[E_T] = \frac{K_M[E \cdot S]}{[S]} + [E \cdot S] = [E \cdot S] \left(\frac{K_M}{[S]} + 1 \right)$$

$$[E \cdot S] = \frac{[E_T]}{\left(1 + \frac{K_M}{[S]}\right)}$$



Nicholas McKnight

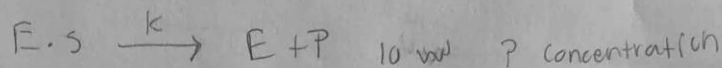
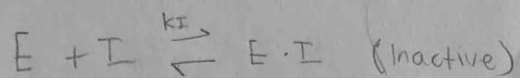
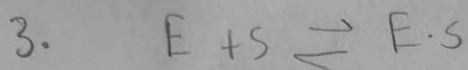


$$C_E^* = C_E + C_{ES_1} + C_{ES_1S_2} = \frac{C_{ES_1}}{k_{-1} C_{S_1}} + C_{ES_1} + k_{II} C_{S_2} C_E$$

$$\text{Use } k_{II} = \frac{C_{ES_1S_2}}{C_{ES_1} C_{S_2}} \rightarrow C_{ES_1} = \frac{C_{ES_1S_2}}{k_{II} C_{S_2}}$$

Nicholas McKnight

#W #2



$$Y_P = k[E \cdot S] \text{ --- (1)}$$

$$K_M = \frac{[E][S]}{[E \cdot S]} ; K_I = \frac{[E][I]}{[E \cdot I]}$$

total enzyme concn.

$$[E_T] = [E] + [E \cdot S] + [E \cdot I]$$

$$[E_T] = [E] + \frac{[E][S]}{K_M} + \frac{[E][I]}{K_I}$$

$$[E_T] = [E] \left(1 + \frac{[S]}{K_M} + \frac{[I]}{K_I} \right)$$

$$[E] = \frac{[E_T]}{\left(1 + \frac{[S]}{K_M} + \frac{[I]}{K_I} \right)} \text{ --- (2)}$$



3. Continue

from Eqⁿ ① + ②

$$r_p = \frac{k[E][S]}{k_m} = \frac{k[S][E_T]}{k_m \left(1 + \frac{[S]}{k_m} + \frac{[I]}{K_I} \right)}$$

$$r_p = \frac{V_{max}[S]}{k_m \left(1 + \frac{[S]}{k_m} + \frac{[I]}{K_I} \right)}$$

where

$$(V_{max} = k[E_T])$$

$$r_p = \frac{V_{max}[S]}{k_m \left(1 + \frac{[I]}{K_I} \right) + [S]}$$

Nicholas
McKnight

Home work #2

6. given

Slope: $m = 0.001$; Intercept = 0.1

$$\text{Lineweaver} - \frac{1}{(-r_s)} = \frac{1}{V_{\max}} + \frac{K_M}{V_{\max}} \left(\frac{1}{C_S} \right)$$

line equation - $y = mx + c$

Slope: $m = \frac{K_M}{V_{\max}}$ and intercept: $c = \frac{1}{V_{\max}}$

$$\therefore c = 0.1$$

$$\frac{1}{V_{\max}} = 0.1 \rightarrow V_{\max} = \frac{1}{0.1} = 10 \text{ (mol m}^{-3} \text{ s}^{-1})$$

$$m = 0.001$$

$$\Rightarrow \frac{K_M}{V_{\max}} = 0.001 \rightarrow \frac{K_M}{10} = 0.001 \rightarrow K_M = 0.01 \text{ (mol m}^{-3})$$

Michaelis-Menten equation -

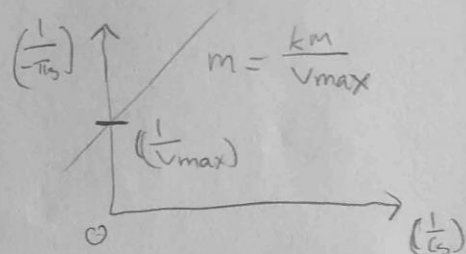
$$(-r_s) = \frac{V_{\max} C_S}{K_M + C_S} ; K_M \text{ and } V_{\max} \text{ are Michaelis-Menten kinetic parameters}$$

6. continued

Arranging previous equation:

$$\frac{1}{(-r_s)} = \frac{k_M + C_s}{v_{\max} C_s} \rightarrow \frac{1}{(-r_s)} = \frac{k_M}{v_{\max} C_s} + \frac{C_s}{v_{\max} C_s}$$

$$\boxed{\frac{1}{(-r_s)} = \frac{k_M}{v_{\max}} \cdot \left(\frac{1}{C_s}\right) + \frac{1}{v_{\max}}}$$



This is the equation for Lineweaver-Burk Plot.

This equation is derived from Michaelis-Menten equation. So you can find the value of Michaelis-Menten kinetic parameters using the value of slope and intercept of Lineweaver-Burk plot.

BELOW AVERAGE

HW - Bioeng.

$$1. \quad k = \frac{k_1 + k_r}{k_1}$$

$$v = \frac{V[S_1]}{k + [S_1]}$$

$$\frac{1}{2}V = \frac{V[S_1]}{\frac{k_1 + [S_1]}{k_1}}$$

$$k_1 + [S_1] = \frac{2V[S_1]}{V}$$

$$k_1 = [S_1]$$

$$2. \quad \frac{d[P]}{dt} = k_p[ES_1]$$

$$\frac{d[ES_1]}{dt} = 0 = k_1[S_1][E] - k_{11}[S_1][E_1] - k_p[ES_1]$$

$$[ES_1] = \frac{k_1[S_1][E]}{k_{11}[S_1] + k_p}$$

$$[E] = [E_0] - [E \cdot S_1]$$

$$[ES_1] = \frac{k_1[S_0]([E_0] - [E \cdot S_1])}{k_{11}[S_1] + k_p}$$

$$= \frac{k_1[S_0][E_0]}{k_{11}[S_0] + k_1 + k_1[S_0]}$$

$$= \frac{k_1[S_0][E_0]}{[S_0](k_{11} + k_1) + k_p}$$

$$= \frac{[S_0][E_0]}{[S_0](\frac{k_{11}}{k_1} + 1) + \frac{k_p}{k_1}}$$

$$= \frac{[S_0][E_0]}{[\frac{k_{11}[S_0]}{k_1} + [S_0] + \frac{k_p}{k_1}]}$$

$$\left[\frac{d[P]}{dt} \right]_0 = r_0 = \frac{k_2[E_0][S_0]}{\left[\frac{k_{11}[S_0] + k_p}{k_1} + [S_0] \right]}$$

3. Rate $k_2[E \cdot S]$

$$k_1 = \frac{[E][S]}{[E \cdot S]}, [E \cdot S] = \frac{[E][S]}{k_1}$$

$$k_i = \frac{[E][I]}{[E \cdot I]}, [E \cdot I] = \frac{[E][I]}{k_i}$$

$$\begin{aligned} [E_T] &= [E] + [E \cdot S] + [E \cdot I] \\ &= [E] + \frac{[E][S]}{k_1} + \frac{[E][I]}{k_i} \\ &= [E] \left(1 + \frac{[S]}{k_1} + \frac{[I]}{k_i} \right) \end{aligned}$$

$$E_T = [E] \left(1 + \frac{[S]}{k_1} + \frac{[I]}{k_i} \right)$$

$$[E] = \frac{E_T}{1 + \frac{[S]}{k_1} + \frac{[I]}{k_i}}$$

$$= \frac{E_T}{\left(1 + \frac{[S]}{k_1} + \frac{[I]}{k_i} \right)}$$

$$[E \cdot S] = \frac{[E][S]}{k_1}$$

$$= \frac{E_T [S]}{k_1 \left(1 + \frac{[S]}{k_1} + \frac{[I]}{k_i} \right)}$$

No - 1

$$\begin{aligned} \text{Rate} &= k_2 [E \cdot S] \\ &= \frac{V_{\max} [S]}{k_1 \left(\frac{1 + [I]}{k_i} \right) + [S]} \end{aligned}$$

-?

? 4)

$$5. \quad y = \frac{y_{\max} C_s}{k_m + C_s}$$

$$\frac{1}{y} = \frac{k_m + C_s}{y_{\max} C_s}$$

$$= \frac{k_m}{y_{\max}} \cdot \frac{1}{C_s} + \frac{1}{y_{\max}}$$

$$y = \frac{1}{x}$$

slope: $m = \frac{k_m}{y_{\max}} = \frac{0.03 \text{ mol l}^{-1}}{13 \text{ mol l}^{-1}} = 0.002$ ✓

x-int: $x = \frac{1}{y} = \frac{1}{0.03} = 33.33$

y-int: $c = \frac{1}{y_{\max}} = \frac{1}{13} = 0.077$ ✓

6) ? -1.5

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Homework 3

TOPICS COVERED IN Homework 3

3. Bioreactor Design

BIOENGINEERING SPRING 2022

Homework Questions and Solution for Homework 3

CHEG 4153 Homework 3

- 1). Briefly describe the four steps in cell growth in a batch reactor.
- 2). Derive the cell concentration variation with time for the exponential growth period.
- 3). Derive the mass balance equations for cell growth and substrate consumption in a batch reactor. Ignore the lag period and use a death period.
- 4). Derive the mass balance equations for cell growth and substrate consumption in an ideal CSTF. Ignore the lag and death periods.
- 5). Graphically compare a batch and a CSTF. Justify with equations.
- 6). Same graphical comparison for a combination of two reactors in series. Justify with equations.

CHEG 4153 HW: 3

- 1)
 - a) LAG PERIOD - CELLS DON'T GROWTH
 - b) EXPONENTIAL GROWTH - NAME
 - c) STATIONARY PERIOD - CELL NUMBER CONSTANT
 - d) DEATH PERIOD - CELL DIE EXPONENTIALLY.

2) EXPONENTIAL PERIOD

$$\frac{dC_X}{dt} = \mu C_X \Rightarrow \int_{C_0}^{C_t} \frac{dC_X}{C_X} = \int_{t_0}^t \mu dt \Rightarrow C_X = C_0^0 e^{\mu(t-t_0)}$$

3) BATCH (EXPONENTIAL)

$$r_X - o_X + \text{GEN.} = \text{ACC.}$$

$$r_X V_R = \frac{dC_X}{dt} = \mu C_X V_R = \frac{\mu \cdot \mu_0 C_S C_X V_R}{K_S + C_X} \quad \text{ADD AFTER}$$

$$Y_{X/S} = -\frac{dC_X}{dC_S}$$

$$dC_X = -Y_{X/S} dC_S$$

$$\frac{dC_S}{dt} = -\frac{\mu_{max} C_S C_X}{Y_{X/S} (K_S + C_X)} \quad \text{NO DEATH}$$

$$4) \quad I_n - o_n + \text{GEN.} = 0$$

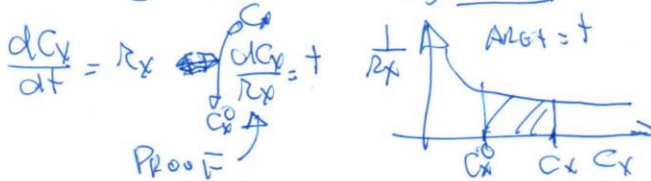
$$C_X^0 \dot{V}^0 - C_X \dot{V} + r_X V_R = 0 \quad \text{IF } \dot{V}^0 = \dot{V}$$

$$\frac{\dot{V}}{V_R} (C_X^0 - C_X) + r_X = 0$$

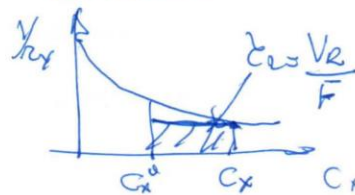
USING $Y_{X/S} = -\frac{\Delta C_X}{\Delta C_S} \Rightarrow \frac{\dot{V}}{V_R} (C_S - C_S^0) + r_X = 0$ You can use $r_X = \frac{\mu_{max} C_S}{K_S + C_S}$

5) GRAPHS

a) BATCH

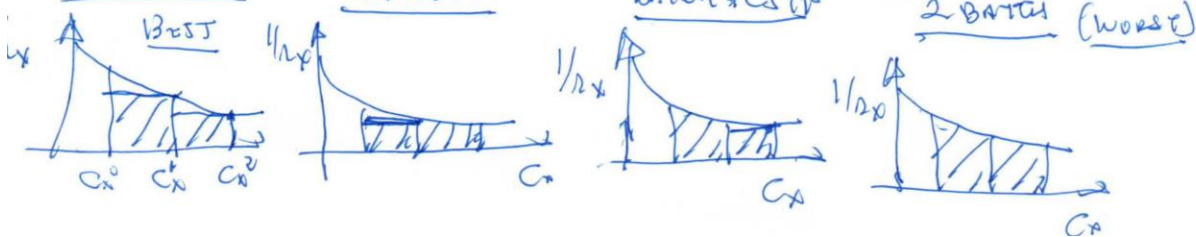


b) CSTF



6) COMPARING AREAS

SMALLER AREAS MORE EFFICIENT ROTATIONS - BATCH + CSTF



ABOVE AVERAGE

Timothy Waugh

Homework 3

1) Four steps in cell growth in a batch reactor:

1. Lag phase: A period of time when the change of cell number is 0.

2. Exponential growth phase: Cell number increases exponentially as the cells start to divide.

3. Stationary phase: The cell population will reach a maximum value and won't increase any further.

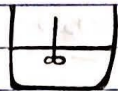
4. Death phase: Cells start to die and the number of viable cells decrease.

$$2) \frac{dx}{dt} = \mu X \rightarrow \frac{dx}{x} = \mu dt \rightarrow \int_{x_0}^x \frac{dx}{x} = \mu \int_0^t dt$$

$$[\ln x]_{x_0}^x = \mu t \rightarrow \ln x - \ln x_0 = \mu t \rightarrow \ln \frac{x}{x_0} = \mu t$$

$$\frac{x}{x_0} = e^{\mu t} \rightarrow \boxed{x = x_0 e^{\mu t}}$$

3)



Sys: Batch reactor

$$In - out + Gen = Acc$$

$$Gen = Acc \rightarrow \frac{dx}{dt} = R_x = \mu X, \mu = \frac{\mu_{max} S}{K_M + S}$$

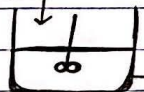
$$\frac{dx}{dt} = \frac{\mu_{max} S X}{K_M + S}$$

$$Y = - \frac{dx}{ds} \cdot \frac{dt}{dt}$$

$$= - \frac{dx/dt}{ds/dt} \rightarrow \frac{dx}{dt} = -Y \frac{ds}{dt} \rightarrow$$

$$\frac{\mu_{max} S X}{K_M + S} = -Y \frac{ds}{dt} \rightarrow \boxed{-\frac{ds}{dt} = \frac{\mu_{max} S X}{Y(K_M + S)}}$$

4)



Sys: CSTR reactor

$$In - out + Gen = Acc$$

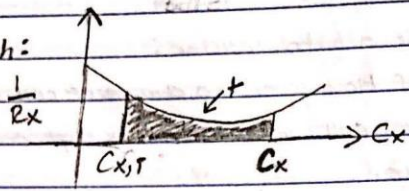
$$F_i C_{x,i} - F C_x + V_R R_x = 0, F_i = F \rightarrow V_R = \frac{F(C_x - C_{x,i})}{R_x}$$

$$\tau_R = \frac{V_R}{F} = \frac{(C_x - C_{x,i})}{R_x}, R_x = \mu C_x \rightarrow \tau_R = \frac{V_R}{F} = \frac{(C_x - C_{x,i})}{\mu C_x}$$

$$\mu = \frac{\mu_{max} C_s}{K_M + C_s} \rightarrow \boxed{\tau_R = \frac{(C_x - C_{x,i})}{\mu_{max} C_s C_x} (K_M + C_s)}$$

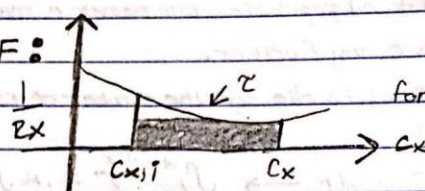
$$Y = - \frac{\Delta C_x}{\Delta C_s} = - \frac{C_x - C_{x,i}}{C_s - C_{s,i}} \rightarrow \boxed{\tau_R = - \frac{(C_s - C_{s,i}) Y}{\mu_{max} C_s C_x} (K_M + C_s)}$$

5. Batch:



$$\text{for } \int_{C_{x,i}}^{C_x} \frac{dC_x}{R_x} = \int_0^t dt = t$$

CSTR:

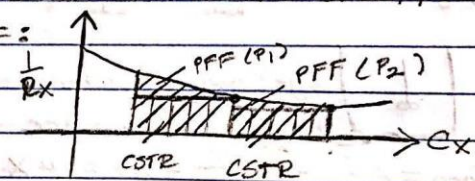


$$\text{for } \tau = \frac{V_R}{F} = \frac{C_x - C_{x,i}}{R_x}$$

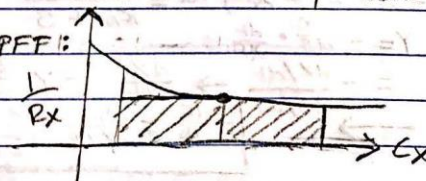
A CSTR is better because it has a smaller area than the batch meaning it requires less residence time.

6. CSTR - CSTR vs PFF - PFF vs CSTR - PFF vs PFF vs CSTR

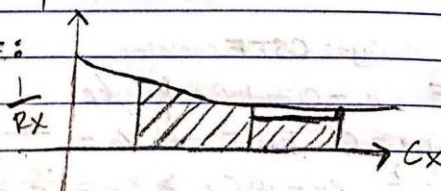
CSTR - CSTR and PFF - PFF:



CSTR - PFF:



PFF - CSTR:



Based on the least amount of area and residence time, the rankings of the best reactors in series are:

1. CSTR - CSTR
2. CSTR - PFF
3. PFF - CSTR
4. PFF - PFF

AVERAGE

Homework 3

1. The four steps in a batch reactor is: Lag phase, log (exponential) phase, stationary phase, death phase.

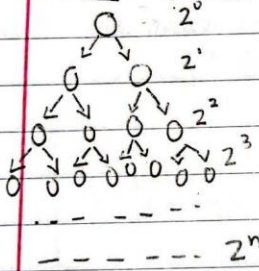
Lag phase: A period of time when the change of cell number is zero.

Exponential phase: Cell number increases exponentially as cells start to divide. Growth rate increase, but division rate proportional is constant at maximum value.

Stationary phase: cell population will reach maximum value & will not increase

Death phase: Nutrients available for cells depleted, cells starts to die & number of viable cells will decrease

2. Exponential cell division:



cell growth mathematically can be describe during exponential

phase: $\frac{dx}{dt} = \mu x$

λ - number or mass of cells (mass/vol.)

$t = \text{time}$

 μ -specific growth rate (1/time)

Time taken for a cell division to occur is called generation time

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

$$\Rightarrow \int_{x_0}^x \frac{dx}{x} = \mu \int_0^t dt$$

$$\Rightarrow \ln x - \ln x_0 = \mu t$$

$$\Rightarrow \ln \frac{x}{x_0} = \mu t$$

$$\Rightarrow \frac{x}{x_0} = e^{\mu t}$$

$$\Rightarrow x = x_0 e^{\mu t}$$

For x to be doubled

$$\frac{x}{x_0} = 2$$

Therefore $2 = e^{\mu t}$

t = generation time

$$t = \frac{\ln \left(\frac{x}{x_0} \right)}{\mu}$$

3. Specific growth rate is quantified by eqn:

$$\mu = \frac{1}{x} \cdot \frac{dx}{dt}$$

x = cell mass concentration (g/L)

t = time (h)

Relationship between specific growth rate & substrate utilization has been made by Monod.

$$\mu = \frac{\mu_{\max} S}{(K_s + S)} \quad y_{x/s} = \frac{dx}{ds} \quad \mu = \frac{y_{x/s}}{x} \cdot \frac{ds}{dt} = y_{x/s} q$$

3(cont.) maintenance expressed as threshold substrate concentration

' S_{min} '

$$S = \frac{K_s D}{(\mu_{max} - D)} + S_{min}$$

$$\mu = \frac{(\mu_{max} + m) \cdot S}{(K_s + S) + m}$$

4. Cell balance:

$$V_R \frac{dx}{dt} = FX_0 - FX + (V_R \mu_g X - V_R k_d X)$$

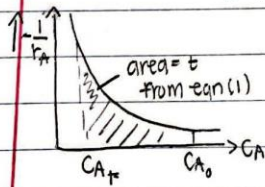
$$\frac{dx}{dt} = DX_0 + (\mu_g - k_d - D) X$$

Substrate balance:

$$V_R \frac{ds}{dt} = FS_0 - FS + V_R \left(-\frac{\mu_g X}{Y_{X/S}} - \frac{q_p X}{Y_{P/S}} - m_s X \right)$$

5. For a batch reactor

$$t = C_{A_0} \int_0^{x_A} \frac{dx_A}{(-r_A)} \dots (1)$$

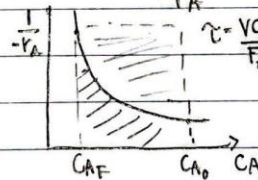


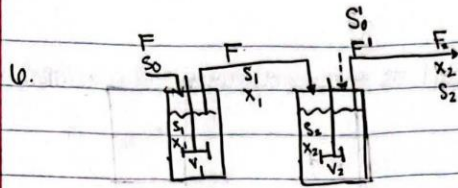
For a CSTR reactor

$$\text{Resistance time } (\tau) = \frac{V}{v} = \frac{C_{A_0} - C_{A_F}}{-r_A}$$

$$\tau = \frac{C_{A_0} X_{A_F}}{-r_A}$$

$$\tau = \frac{V C_{A_0}}{F_{A_0}} = \frac{C_{A_0} - C_{A_F}}{-r_A}$$





$$V_1 \frac{dX_1}{dt} = FX_0 - FX_1 + \mu_{net,1} X_1 V_1$$

$$V_2 \frac{dX_2}{dt} = FX_1 + F'X_0 - (F+F')X_2 + \mu_{net,2} X_2 V_2$$

At steady state with $X_0 = 0$

$$0 = FX_1 - (F+F')X_2 + \mu_{net,2} X_2 V_2 \Rightarrow \mu_{net,2} = \frac{F+F'}{V_2} - \frac{F}{V_2} \frac{X_1}{X_2} = D_2 - \frac{F}{V_2} \frac{X_1}{X_2}$$

(For a 1st reactor)

BELOW AVERAGE

1. Four steps in cell growth in a batch reactor

1. G1 stage, gap 1: The cell increases in size

2. Synthesis: copies DNA

3. G2: prepares to divide

4. Mitosis: it divides

2. Derive cell concentration

t_g = generation time

g = number of generations

After one generation $n_1 = 2$

$$g = \frac{t}{t_g}$$

After two generations $n_2 = 2 \times 2 = 4$

After three generations $n_3 = 2 \times 2 \times 2 = 8$

Cell concentration variation for time

$$n_g = 2^{t/t_g} n_0$$

OR

$$\ln(n_g) = \ln 2 \frac{t}{t_g} + \ln(n_0)$$

3. Derive mass balance equation for cell growth (Batch reactor)

Specific growth rate equation

$\mu = \frac{1}{x} \cdot \frac{dx}{dt}$ x = cell concentration (g/L)

t = time (h)

$$\mu = \mu_{max} \frac{S}{K_s + S} \quad Y_{x/s} = \frac{dx}{ds}$$

$$\mu = Y_{x/s} \cdot \frac{ds}{dt} = Y_{x/s} q$$

$$S = K_s D / (\mu_{max} - D) + S_{min} \quad \mu = (\mu_{max} + m) \cdot S / (K_s + S) - m$$

4. Derive mass balance equation for cell growth and substrate (Ideal CSTR)

Specific growth rate equation

$\mu = \frac{1}{x} \cdot \frac{dx}{dt}$ x = cell mass concentration

$$\mu = \mu_{max} \frac{S}{K_s + S} \quad Y_{x/s} = \frac{dx}{ds}$$

$$\mu = Y_{x/s} / x \cdot \frac{ds}{dt} = Y_{x/s} q$$

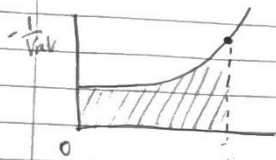
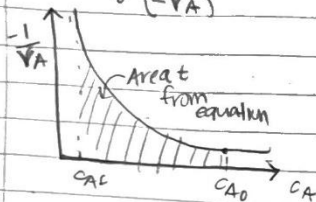
$$S = K_s D / (\hat{A}_{u\max} - D) + S_{\min}$$

$$\hat{A}_u = (\hat{A}_{u\max} + m) \cdot S / (K_s + S) - m$$

5. Compare batch and CSTR graphically

Batch reactor

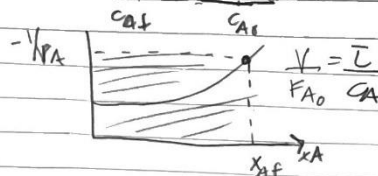
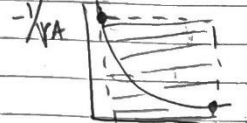
$$t = C_A \int_0^{x_A} \frac{dx_A}{(-r_A)} \quad \text{--- (1)}$$



CSTR reactor

$$\tau = \frac{C_A - C_{Ae}}{-r_A}$$

$$\tau = \frac{C_A \cdot x_A}{-r_A}$$



6. Compare combination of two reactors Graphically

for 1st reactor $\tau_1 = \frac{C_0(x_1 - x_0)}{-r_A}$

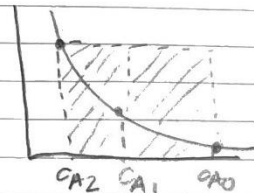
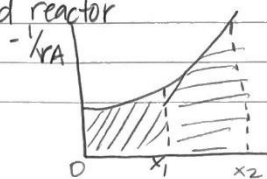
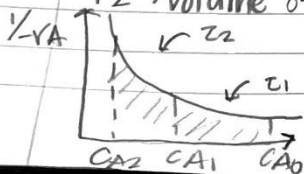
for 2nd reactor $\tau_2 = \frac{C_0(x_2 - x_1)}{-r_A}$

When two reactors of CSTR are in series then the overall conversion will be high

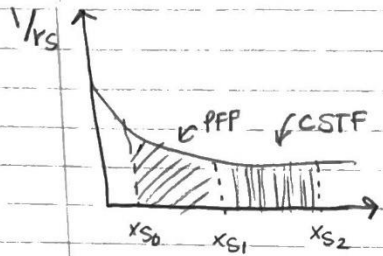
$$\frac{C_0}{C_2} = (1 + K\tau)^2$$

$V_1 \rightarrow$ volume of 1st reactor

$V_2 \rightarrow$ volume of 2nd reactor



combination of CSTFs and PPFs



**BIOENGINEERING
SPRING 2022**

Title of Assignment: Homework 4

TOPICS COVERED IN Homework 4

- 1. Transport Phenomena in Biological Systems**
- 2. Sterilization**

BIOENGINEERING SPRING 2022

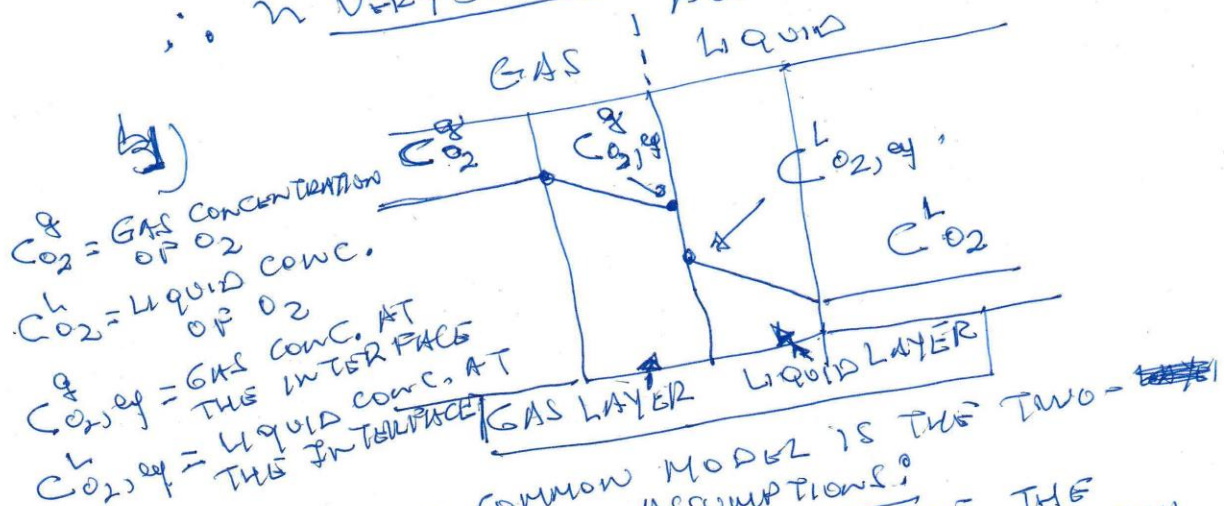
Homework Questions and Solution for Homework 4

CHEG 4315 Homework 4

- 1). Derive the equation describing the time variation of the amount of microbes during the sterilization process.
- 2). Propose an acceptable $\square$ value. Justify your choice with equations.
- 3). Which model do you use to calculate the gas-liquid mass transfer? List the two main assumptions.
- 4). Draw a schematic of the two-layer model including the real and assumed concentrations profiles in both phases. Name all relevant concentrations.
- 5). Write the equation for molar flow of oxygen from air into a liquid phase. Name all terms.
- 6). Assuming that there is significant resistance in both phases write the global mass transfer coefficient equation from the gas and from the liquid side.
- 7). Assuming that there is no resistance in gas phase write the equation for the global mass transfer coefficient from the liquid side.
- 8). Assuming that there is no resistance in liquid phase write the equation for the global mass transfer coefficient from the gas side.

1) $\frac{dn}{dt} = -bn$ $\Rightarrow \int \frac{dn}{n} = -b \int dt$
 $\ln \frac{n}{n_0} = -b(t-t_0)$ OR $n = n_0 e^{-b(t-t_0)}$

2) $\ln \frac{n_0}{n} = \Delta \approx 30 \Rightarrow n = n_0 / e^{30}$
 $\therefore n$ VERY SMALL BECAUSE MICROBES CAN GROW AGAIN.



3) THE MOST COMMON MODEL IS THE TWO-LAYERS MODEL. ASSUMPTIONS:

a) ALL MASS TRANSFER INSIDE THE TWO LAYERS. OUTSIDE ALL CONCENTRATIONS ARE CONSTANTS.

b) THE CHANGE OF CONCENTRATIONS INSIDE THE LAYERS ARE LINEAR.

5) $\dot{n}_{O_2} = k_{G,A_G} (C_{O_2}^g - C_{O_2,eq}^g) = k_{L,A_{GL}} (C_{O_2,eq}^l - C_{O_2}^l)$
 GAS MASS TRANSFER COEFFICIENT $\uparrow$ INTERFACE AREA $\uparrow$ LIQUID MASS TRANSFER COEFFICIENT

6) GAS SIDE $\dot{n}_{O_2} = K_G A_{GL} (C_{O_2}^g - H C_2^L) \dots$
LIQUID SIDE $\dot{n}_{O_2} = K_L A_{GL} \left(\frac{C_{O_2}^g}{H} - C_2^L \right)$

7) $k_g \gg k_L$ MEANS NO RESISTANCE ON GAS PHASE
LIQUID SIDE $\frac{1}{k_L} = \frac{1}{k_L} + \frac{H}{k_g} \xrightarrow{\approx 0} \boxed{k_L \approx k_L}$
 FROM 6)

8) $k_L \gg k_g$ MEANS NO RESISTANCE ON LIQUID PHASE
 $\frac{1}{k_g} = \frac{1}{k_g} + \frac{1}{k_L H} \xrightarrow{\approx 0} \boxed{k_g \approx k_g}$

IN 7) AND 8) YOU USE:

$\rightarrow i \xrightarrow{R_1} M \xrightarrow{R_2} M \xrightarrow{i}$ $R_T = R_1 + R_2$
 $R_1 = R_G = \frac{1}{k_g}$, $R_2 = R_L = \frac{1}{k_L}$

YOU NEGLECT THE SMALLER RESISTANCE $\left(\frac{1}{k_i} \right)$
 VERSUS THE OTHER $i = G \text{ OR } L$



ABOVE AVERAGE

CHEG 4153

Homework 4

- 1). Derive the equation describing the time variation of the amount of microbes during the sterilization process.
- 2). Propose an acceptable Δ value. Justify your choice with equations.
- 3). Which model do you use to calculate the gas-liquid mass transfer? List the two main assumptions.
- 4). Draw a schematic of the two-layer model including the real and assumed concentrations profiles in both phases. Name all relevant concentrations.
- 5). Write the equation for molar flow of oxygen from air into a liquid phase. Name all terms.
- 6). Assuming that there is significant resistance in both phases write the global mass transfer coefficient equation from the gas and from the liquid side.
- 7). Assuming that there is no resistance in gas phase write the equation for the global mass transfer coefficient from the liquid side.
- 8). Assuming that there is no resistance in liquid phase write the equation for the global mass transfer coefficient from the gas side.

#1 Equation describing time variation of the amount of microbes during the sterilization process

$$n \rightarrow \frac{N^0 \text{ microbes}}{m} \quad \div \quad A_{\text{dev}} = \pi \rightarrow \frac{N^0 \text{ microbes}}{m}$$

$\downarrow$
 $1/m^2$

Recall $\frac{dn}{n} = -kd \, dt$ $\rightarrow$ $\int_{n_0}^n \frac{dn}{n} = -kd \int_0^t dt$

$\downarrow$
death constant

$$\Delta_{\text{design}} = 30 \rightarrow \ln \frac{n}{n_0} = \ln \frac{n_0}{n} = \Delta = kdt$$

$$\Delta = \ln \frac{n_0}{n} = 30$$

Therefore:

$$e \cdot \frac{n_0}{n} = e^{30}$$

or

$$\frac{n}{n_0} = e^{-30}$$

where $n = n_0 \cdot e^{-30}$

(#2) Acceptable Δ value?

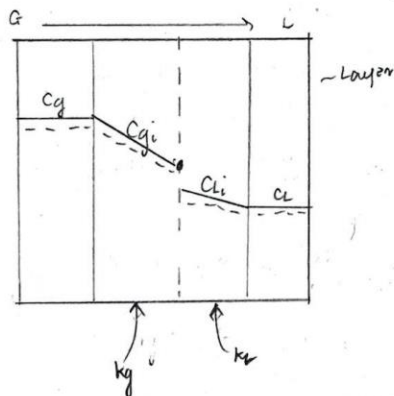
$$n^0 = 10^{12} ; k_{el} = \frac{1}{101} \text{ hrs}^{-1}$$

$$t_{min} = \frac{30}{100 \text{ hrs}^{-1}} = \frac{0.3 \text{ hr}}{1 \text{ hr}} \times \frac{3600 \text{ sec}}{1 \text{ hr}} \sim \sim 1080 \text{ seconds}$$

(#3) Model used to calculate the gas-liquid mass transfer are:

- (1) Mass transfer occurs linearly
- (2) Outside is at a constant

(#4) Schematic of 2-layer model



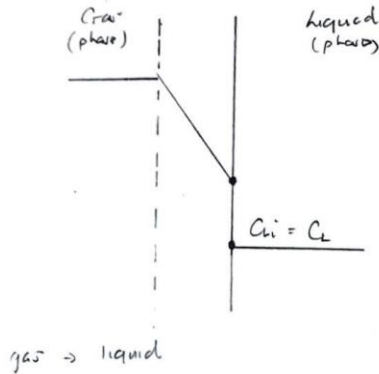
4 concentrations within model; C_g, C_{gi}, C_i, C_l

(#5) Equation for molar flow of Oxygen from air into a liquid phase.

$$\begin{aligned} \text{Flux} \quad J_{O_2} &= \overset{\substack{\uparrow \\ \text{MT constant}}}{k_g} \Delta C_g = k_g (C_g - C_{gi}) \\ &\quad \downarrow \text{driving force} \\ &\quad \downarrow \\ &\quad \frac{n^0 \text{ moles } O_2}{m^2 s} \\ &\quad \downarrow \\ &\quad \text{Interfacial area} \end{aligned}$$

(46) Global mass transfer coefficient equation from the gas and from liquid side

Only one resistance



$$\begin{aligned} &\rightarrow \\ &\Delta C \\ &\downarrow \\ &(C_g - C_L) \end{aligned}$$

$$J_g = J_L$$

$$k_g \Delta C_g = k_L \Delta C_L$$

$$\text{Since } \Delta C_g \sim (C_g - C_{gi})$$

$$\Delta C_L \sim (C_L - C_i)$$

$$k_g (C_g - C_{gi}) = k_L (C_L - C_i)$$

$$k_g C_g + k_L C_L = k_L H_{cc} C_{gi} - k_L C_L$$

$$\text{Recall } H_{cc} \equiv \frac{C_{gi}}{C_{gi}}$$

$$k_g C_g + k_L C_L = C_{gi} (k_L H_{cc} + k_g) \rightarrow \text{Therefore } J_g = k_g C_g - \frac{k_g^2 C_g + k_g k_L C_L}{(k_L H_{cc} + k_g)}$$

$$J_g = \frac{(k_L H_{cc} + k_g) (k_g C_g)}{(k_L H_{cc} + k_g)} \rightarrow \frac{k_g^2 C_g + k_g k_L C_L}{k_L H_{cc} + k_g}$$

OR

$$\frac{k_g k_L H_{cc} C_g + k_g^2 C_g}{(H_{cc} k_L + k_g)} + \frac{-k_g^2 C_g - k_g k_L C_L}{(H_{cc} k_L + k_g)}$$

$$\text{Where: } J_g = \frac{k_g k_L (H_{cc} C_g - C_L)}{H_{cc} k_L + k_g} \rightarrow \text{for gas to liquid}$$

?

$$J_L = \frac{k_L (C_{gi} - C_L)}{H_{cc}} \rightarrow \text{for liquid to gas}$$

(H7) Assuming no resistance for gas phase, equation for global mass transfer

$$k_g = \left(\frac{H_{cc}}{k_g} + \frac{1}{k_L} \right)^{-1}$$

for non-resistance $\frac{1}{k_g} = 0$

(

$$k_g = \left(\frac{H_{cc}}{k_g} + \frac{1}{\cancel{k_L}} \right)^{-1} = k_g = \left(\frac{H_{cc}}{k_g} \right)^{-1} = \boxed{k_g \approx \frac{k_g}{H_{cc}}}$$

(H8) Assuming no resistance for liquid phase

$$k_g = \left(\frac{H_{cc}}{\cancel{k_g}} + \frac{1}{k_L} \right)^{-1} = \boxed{k_g \approx k_L}$$

AVERAGE

2)

Homework #4

1. Derive eqn for time variation

$$\frac{dn}{dt} = -k_d \cdot n \quad X = \frac{n}{A} \quad \text{where } X = \frac{\text{microbes}}{\text{m}^2} \quad \frac{n}{A} = \frac{\text{microbes}}{\text{area}}$$

$$n_0 \int_{n_0}^n \frac{dn}{n} = - \int_0^t k_d dt \rightarrow \ln \frac{n}{n_0} = - \int_0^t k_d dt \rightarrow \ln \frac{n}{n_0} = -k_d t$$

$$k_d = \text{constant} \quad \Delta = \ln \frac{n_0}{n} = k_d t \rightarrow t = \frac{\Delta}{k_d} \rightarrow \text{time to reduce } n_0 \rightarrow n$$

2. Acceptable Δ value, justify w/ eqns.

For a desired value $n = 0.001$

$$\Delta = \ln \frac{n_0}{n} = \ln \frac{10^4}{0.001} = 29.93 \approx 30 = \Delta$$

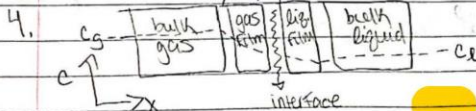
$$\text{For } n_0 = 10^4, n = 0.001 = 10^{-3} \quad \Delta = \ln \frac{10^4}{10^{-3}} = 39.14 = \Delta$$

3. model for gas-liquid mass transfer; 2 main assumptions

1) concentrations change within the films is linear & changes with position

2) equilibrium will be attained at interface & flux is in x direction

Model = Two Film theory



5. eqn for molar flow of oxygen from air into liquid phase

$N_A^{\text{gas-liquid}}$ oxygen moves from gas phase to gas-liquid interface

N_A = rate of mass transfer k_g & k_L = mass transfer coeff. for gas & liquid

$$N_A^{\text{gas-liquid}} = N_A^{\text{liquid-liquid}}$$

$$N_A^{\text{gas-liquid}} = k_g (C_{A01}^g - C_{A12}^g) = N_A^{\text{liquid-liquid}} = k_L (C_{A12}^l - C_{A02}^l)$$

$$C_{A12}^l = C_{A12}^g m, \quad m = \text{Henry's constant}$$

$$N_A^{\text{gas-liquid}} = k_g (C_{A01}^g - m C_{A02}^l)$$

6. assume significant resistance in both phases write the global mass transfer coeff. eqn from gas & from liq side

$$J = K_L \left(\frac{J}{K_L} + \frac{J}{H \cdot K_G} \right) \quad J = K_G \left(\frac{J}{K_G} + \frac{J}{H \cdot K_L} \right)$$

total resistance $\frac{1}{K_L} = \frac{1}{K_L} + \frac{1}{H \cdot K_G} \quad \frac{1}{K_G} = \frac{1}{K_G} + \frac{1}{H \cdot K_L}$

7. Assume no resistance in gas phase write eqn for global mass transfer coeff. from liq side

$$C_{ei} = \frac{C_{gi}}{H} \rightarrow H = \frac{C_{gi}}{C_{ei}}$$

$$J = K_L (C_1 - C_{ei}) \quad \& \quad J = K_G (C_{gi} - C_g)$$

$$K_L = J / (C_1 - C_{ei})$$

8. Assume no resistance in liq phase write eqn for the global mass transfer coeff. from the gas side

$$C_g = \frac{C_{ei}}{H} \rightarrow H = \frac{C_{ei}}{C_g}$$

$$J = K_G (C_g - C_{gi}) \quad \& \quad J = K_L (C_{ei} - C_e)$$

$$K_G = J / (C_g - C_{gi})$$

BELOW AVERAGE

① Derive using time variation
 $\frac{dN}{dt} = -kN$ $k = \text{constant}$
↑ function of t

5.5

$\log N = -kt + \text{constant} \Rightarrow k = \frac{\log \frac{N_0}{N}}{t}$ ✓

② $t=0$; $N=N_0$

$\log N_0 = \text{constant}$

$\log N = -kt + \log N_0$

$\log \left[\frac{N}{N_0} \right] = -kt$

$\frac{N}{N_0} = 10^{-kt}$
↑ # of mice
↑ time
↑ reaction rate constant
↑ initial #

③ Δ value

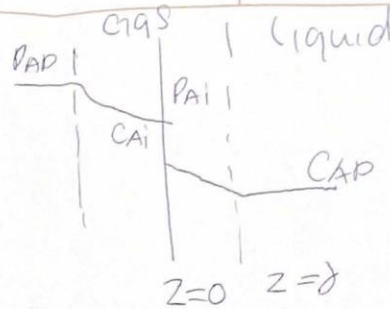
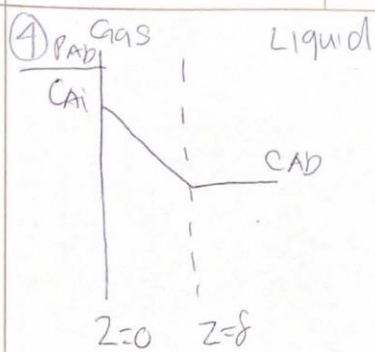
$121^\circ\text{C} - 132^\circ\text{C}$

$250^\circ\text{F} - 270^\circ\text{C}$

must be maintained for
 minimal time to kill microorganisms

③ which model to calculate gas-liquid mass transfer

$J_{A2} = -D_{AB} \frac{dC_A}{dz}$
↑ molecular flux
 $N_A = X_A N - C_{DA} \frac{dx}{dt} A$
↑ molecular flux in species



-1.5

⑤

$$N = k_g(P_g - P_{gi}) = k_L(C_{Li} - C_L)$$

-1.0

⑥ $\frac{1}{k_{yo}} = \frac{1}{k_y} + \frac{m}{k_x}$ liquid $\frac{1}{k_{xo}} = \frac{1}{k_x} + \frac{1}{m k_y}$ ✓

⑦ gas phase $\frac{1}{m k_y}$ is negligible $N_A = k_{yo}(y_{AD} - y_A)$

$$\frac{1}{k_{xo}} \approx \frac{1}{k_x}$$

✓

$$\frac{N_A}{k_{yo}} = \frac{N_A}{k_y} + \frac{m N_A}{k_x}$$

⑧ liquid phase

$$\frac{1}{k_{yo}} = \frac{1}{k_y}$$

✓

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Partial Exam I

TOPICS COVERED IN Partial Exam I

- 1. Chemicals of Life**
- 2. Kinetics of Enzymatic Reactions**

**CHEG 4315
BIOENGINEERING
SPRING 2022**

Partial Exam I Sample Questions

**CHEG 4315
Test 1 A**

1). Write the generic formula for monosaccharides (simple sugar). Monosaccharides present two kind of cyclic structures. How many atoms does the cycle have?

2). Calculate the rate of formation of product. Assume that the following sequence describes the reactions of competitive self-inhibition catalyzed by one enzyme:



3). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.03 \text{ mol L}^{-1}, v_{\max} = 15 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

ABOVE AVERAGE

CHEG 4315

Exam 1 B

1). Which are the main components of RNA? Same for DNA. Which are the attractive pairs of nitrogen bases in RNA?

2). Which are the main functional groups of amino acids? How many structures proteins have? Do NOT describe them.

3). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

4). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.02 \text{ mol L}^{-1}, v_{\max} = 10 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

#1 i) The main components of RNA & DNA are polymers made up of long chains of nucleotides consisting of a sugar molecule either ribose for RNA, deoxyribose for DNA that are attached to a phosphate group and a nitrogen-containing base.

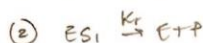
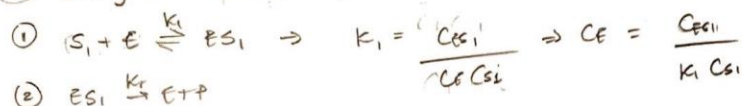
ii) The attractive pairs of nitrogen bases in RNA are adenine (A) and Uracil (U) (purines) as well as Guanine (G) and Cytosine (pyrimidines)

#2 i) Amino acids have 2 main functional groups; composed of an amine ($-NH_2$) and a carboxylic acid ($-COOH$) linked to the same carbon atom.

ii) Proteins have 4 main structures of complexity that are primary, secondary, tertiary, and quaternary

(13) Using the Michaelis-Menten procedure

Chad Gardner page 42



Recall: $[E]^0 = [E] + [ES_1]$ $\therefore$ Since $[E] = \frac{[ES_1]}{K_1 [S_1]}$

Then, $[E]^0 = \frac{[ES_1]}{K_1 [S_1]} + [ES_1]$

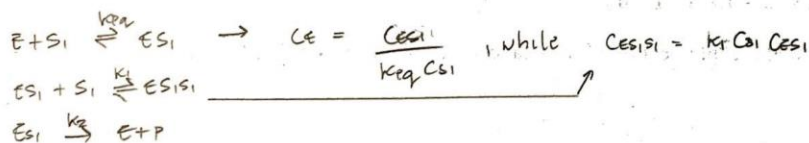
$r_p = k_2 [ES_1] = \frac{k_2 [E]^0 K_1 [S_1]}{1 + K_1 [S_1]}$ since $k_2 [E]^0 = r_{max}$

Therefore $\therefore r_p = \frac{r_{max} [S_1]}{\frac{1}{K_1} + [S_1]}$

Recall: $K_m = 1/K_1$ so, $r_p = \frac{r_{max} [S_1]}{K_m + [S_1]}$

(14) Assuming Michaelis-Menten kinetic parameters for enzymatic reaction

$K_m = 0.02 \text{ mol L}^{-1}$, $r_{max} = 10 \text{ mol L}^{-1} \text{ min}^{-1}$



Since $[E]^0 = [E] + [ES_1] + [ES_1 S_1]$, Recall: $[E] = \frac{[ES_1]}{K_{eq} [S_1]}$ $\therefore [ES_1 S_1] = K_1 [S_1] [ES_1]$

Therefore: $[E]^0 = \frac{[ES_1]}{K_{eq} [S_1]} + [ES_1] + K_1 [S_1] [ES_1]$ $\therefore r_p = \frac{k_2 [E]^0 K_{eq} [S_1]}{1 + K_{eq} [S_1] + K_{eq} K_1 [S_1]^2}$

To justify: $r = \frac{r_{max} [S]}{K_m + [S]}$ where the reverse $\frac{1}{r} = \frac{K_m + [S]}{r_{max} [S]} = \frac{K_m}{r_{max} [S]} + \frac{[S]}{r_{max} [S]}$

Since Lineweaver Burk plot ($1/r$ vs $1/[S]$)

Slope = $\frac{K_m}{r_{max}} = \frac{0.02 \text{ mol L}^{-1}}{10 \text{ mol L}^{-1} \text{ min}^{-1}} = 2 \times 10^{-3} \text{ min}$

= $\frac{K_m}{r_{max}} \left(\frac{1}{[S]} \right) + \left(\frac{1}{r_{max}} \right)$ - slope - intercept

while

Intercept = $\frac{1}{r_{max}} = \frac{1}{10 \text{ mol L}^{-1} \text{ min}^{-1}} = 0.1 \text{ L min mol}^{-1}$

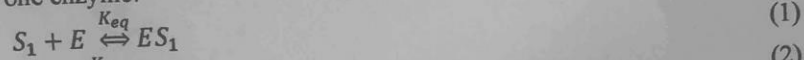
AVERAGE

Nicholas
McKnight

CHEG 4153
Test 1 C



- 1). Which are the main components of lipids? Which is the main function of lipids and fats?
- 2). Assume that the following sequence describes the competitive inhibition reaction catalyzed by one enzyme:



- 3). A substrate is converted to a product by the catalytic action of an enzyme. The slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$) are:

Slope = 0.003, intercept = 0.15.

Calculate the Michaelis-Menten kinetic parameters (K_M and v_{max}) for this enzyme reaction. Justify.

Nicholas
McKnight

CHEG 4153
Test 1C

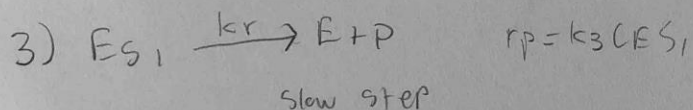
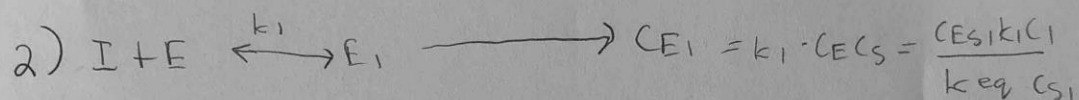
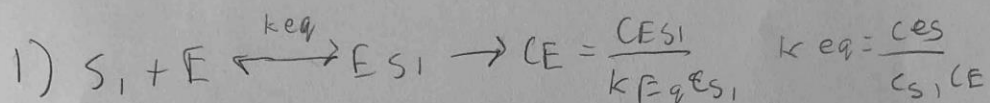
1.) The main components of lipids

are fats and oils. The main functions of lipids and fats include storing energy, signaling, and acting as structural components of cell membranes.

Nicholas
McKnight

CHEG 4153
Test 1 C

2.)



$$CE^0 = CE + CES_1 + CEI = \frac{CES_1}{k_{eq}CS_1} + CES_1 + \frac{k_1 C_I CE}{k_{eq}CS_1}$$

$$r_p = k_r CES_1 = \frac{k_r CE^0 k_{eq} CS_1}{1 + k_{eq} CS_1 + k_1 C_I}$$

3. slope = 0.003
 intercept = 0.15
 $k_m = ?$
 $V_{max} = ?$

$$k_m = (\text{slope})(r_{max})$$

$$(0.003 \text{ min}) (6.67 \frac{\text{mol}}{\text{min} \cdot \text{L}})$$

$$k_m = 0.02 \frac{\text{mol}}{\text{L}}$$

-1 Just.

$$\text{slope} = \frac{k_m}{r_{max}}$$



$$\text{intercept} = \frac{1}{r_{max}}$$



$$0.15 = \frac{1}{r_{max}}$$



$$r_{max} = \frac{1}{0.15}$$

$$r_{max} = 6.67 \frac{\text{mol}}{\text{L} \cdot \text{min}}$$

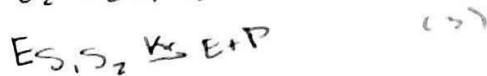
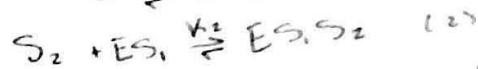
BELOW AVERAGE

1. RNA is made up of ribose thus the name ribonucleic acid. Its nitrogenous bases are adenine (A), guanine (G), uracil (U), cytosine (C). Unlike DNA its single stranded.

DNA or Deoxyribonucleic Acid. It is made up of phosphate group + sugar (ribose) for its back bone. Its nitrogenous bases are Adenine, Guanine, Cytosine + Thymine. To reiterate RNA nitrogen bases are Adenine, Uracil, Cytosine, Guanine.

C - G - U

2.


 $\Rightarrow \text{Eq. 1}$

$$C_E = \frac{C_{ES_1}}{K_1 C_{S_1}}$$

 $\Rightarrow \text{Eq. 2}$

$$C_{ES_1S_2} = K_2 C_{S_2} C_{ES_1}$$

$$\Rightarrow C_E^0 = C_E + C_{ES_1} + C_{ES_1S_2}$$

$$= \frac{C_{ES_1}}{K_1 C_{S_1}} + C_{ES_1} + K_2 C_{S_2} C_{ES_1}$$

$$\Rightarrow r_p = C_{ES_1S_2} + k_3 C_{ES_1S_2}$$

using k_3 to find C_{ES_1}

$$K_2 C_{S_2} C_{ES_1} = C_{ES_1S_2}$$

$$K_2 = \frac{C_{ES_1S_2}}{C_{S_2} C_{ES_1}}$$

$$\Rightarrow C_{ES_1} = \frac{C_{ES_1S_2}}{K_2 C_{S_2}}$$

$$\Rightarrow C_E^0 = \frac{C_{ES_1}}{K_1 C_{S_1}} + \frac{C_{ES_1S_2}}{K_2 C_{S_2}} + C_{ES_1S_2}$$

factor

$$C_E^0 = C_{ES_1S_2} \left(\frac{1 + K_1 C_{S_1} + K_1 K_2 C_{S_1} C_{S_2}}{K_1 K_2 C_{S_1} C_{S_2}} \right)$$

plug in for r_p

~~$r_p = k_3 C_{ES_1S_2} = \frac{k_3 C_E^0 K_2 C_{S_2}}{1 + K_1 C_{S_1} + K_1 K_2 C_{S_1} C_{S_2}}$~~

$$r_p = k_3 C_{ES_1S_2}$$

$$= \frac{k_3 C_E^0 K_2 C_{S_2}}{1 + K_1 C_{S_1} + K_1 K_2 C_{S_1} C_{S_2}}$$

NO
-1
3

3.

$$K_m = .02 \text{ mol L}^{-1}, v_{\text{max}} = 2.0 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calc. Slope + intercept of Linck plot
($1/v$ vs $1/C_s$)

We know that
 $\frac{1}{v}$ vs $\frac{1}{C_s}$

$$v = \frac{v_{\text{max}} C_s}{K_m + C_s} \Rightarrow \frac{1}{v} = \frac{K_m + C_s}{v_{\text{max}} C_s} \Rightarrow \frac{1}{v} = \frac{1}{C_s} \frac{K_m}{v_{\text{max}}} + \frac{1}{v_{\text{max}}}$$

$\therefore \frac{K_m}{v_{\text{max}}} = \text{slope}$

$$\text{slope} = \frac{.02}{2.0} = .01 \text{ min}$$

Intercept: $\frac{1}{v_{\text{max}}}$

~~scribbles~~

$$\frac{1}{2.0} = \frac{\text{min}}{\text{mol}} = .5 \text{ min/mol}$$

CHEG 4153

Test 1 B

1). Which are the main components of RNA? Same for DNA. Which are the attractive pairs of nitrogen bases in RNA?

2). Assume that the following sequence describes the reactions of two different substrates catalyzed by one enzyme:



3). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.02 \text{ mol L}^{-1}, v_{\max} = 20 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Partial Exam II

TOPICS COVERED IN Partial Exam II

- 1. Microbial Life Cycle**
- 2. Bioreactor Design**

**CHEG 4153
BIOENGINEERING**

Exam II Problem Questions

CHEG 4315

Test 2A

- 1). Derive the cell concentration variation with time for the exponential growth period.
- 2). Derive the mass balance equations for cell growth and substrate consumption in a batch reactor. Ignore the lag period and use a death period.
- 3). Graphically compare a batch and a CSTF. Determine which has the smaller volume. Justify with equations.
- 4). Same graphical comparison for all combinations of two reactors, one CSTF and one batch. Determine which combination has the smaller volume. Justify with equations.

ABOVE AVERAGE



CHEG 4315
Test 2A

- 1). Derive the cell concentration variation with time for the exponential growth period.
- 2). Derive the mass balance equations for cell growth and substrate consumption in a batch reactor. Ignore the lag period and use a death period.
- 3). Graphically compare a batch and a CSTF. Determine which has the smaller volume for same $C_A^0 - C_A$ range. Justify with equations.
- 4). Same graphical comparison for all combinations of two reactors, one CSTF and one batch. Determine which combination has the smaller volume. Justify with equations.

Timothy Waugh

CHEG 4315 Test 2A

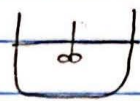
1.) $\frac{dC_x}{dt} = \mu C_x \rightarrow \frac{dC_x}{C_x} = \mu dt \rightarrow \int_{C_{x0}}^{C_x} \frac{dC_x}{C_x} = \int_{t_0}^t \mu dt$

$[\ln C_x]_{C_{x0}}^{C_x} = \mu(t - t_0) \rightarrow \ln C_x - \ln C_{x0} = \mu(t - t_0)$

$\ln \frac{C_x}{C_{x0}} = \mu(t - t_0) \rightarrow \frac{C_x}{C_{x0}} = e^{\mu(t - t_0)} \rightarrow$

$C_x = C_{x0} e^{\mu(t - t_0)}$

2.)



Sys: Batch reactor

In - out + Gen = Acc

Gen = Acc $\rightarrow \frac{dX}{dt} = R_x = \mu X, \mu = \frac{\mu_{max} S}{K_M + S}$

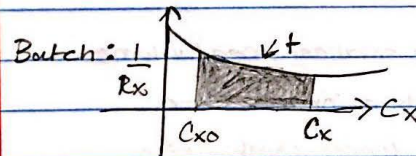
$\frac{dX}{dt} = \frac{\mu_{max} S X}{K_M + S}$

$Y = -\frac{dX}{dS} \cdot \frac{dt}{dt} =$

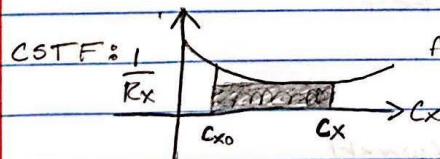
$= -dX/dt \rightarrow \frac{dX}{dt} = -Y \frac{dS}{dt} \rightarrow$

$\frac{\mu_{max} S X}{K_M + S} = -Y \frac{dS}{dt} \rightarrow \frac{dS}{dt} = -\frac{\mu_{max} S X}{Y(K_M + S)}$

3.)



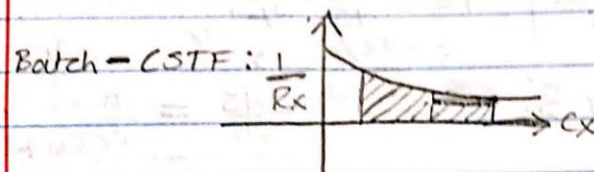
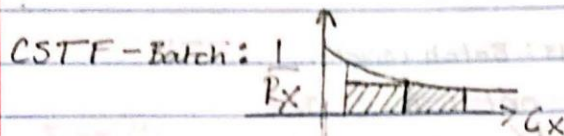
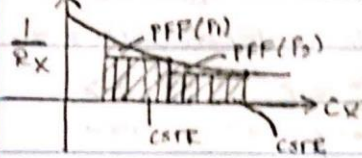
for $\int_{C_{x0}}^{C_x} \frac{dC_x}{R_x} = \int_0^t dt = t$



for $\tau_R = \frac{V_R}{F} = \frac{C_x - C_{x0}}{R_x}$

The CSTF has a smaller area and volume than the batch reactor, meaning it requires less residence time. CSTF > Batch.

4. CSTF - CSTF and Batch - Batch



CSTF - CSTF has the smallest area/volume making it the best combination while the Batch - Batch is the worst combination.

1. CSTF - CSTF (Best)
2. CSTF - Batch
3. Batch - CSTF
4. Batch - Batch (worst)

AVERAGE

CHEG 431S

Test 2A

- 1). Derive the cell concentration variation with time for the exponential growth period.
- 2). Derive the mass balance equations for cell growth and substrate consumption in a batch reactor. Ignore the lag period and use a death period.
- 3). Graphically compare a batch and a CSTF. Determine which has the smaller volume for same $C_A^0 - C_A$ range. Justify with equations.
- 4). Same graphical comparison for all combinations of two reactors, one CSTF and one batch. Determine which combination has the smaller volume. Justify with equations.

Shanell Bryant

Exam #2

2/1/22

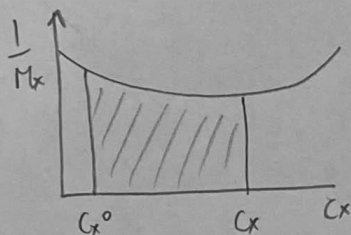
$$\textcircled{1} \frac{dC_x}{dt} = \mu C_x \rightarrow \int_{C_{x0}}^{C_x} \frac{dC_x}{C_x} = \int_{t_0}^t \mu dt \Rightarrow C_x = C_{x0} e^{\mu(t-t_0)}$$

② Derive mass balance equation

$$\mu = \frac{\mu^0 C_s}{K_M + C_s} \rightarrow \frac{dC_x}{dt} = r_x = \mu C_x = \frac{\mu^0 C_s C_x}{K_M + C_s}$$

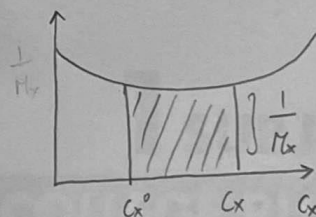
$$\frac{C_s}{C_p} \rightarrow Y = -\frac{\Delta C_x}{\Delta C_s} * \frac{\Delta t}{\Delta t} \rightarrow \frac{dC_p}{dt} = -\frac{dC_s}{dt} = \frac{\mu^0 C_s C_x}{Y(K_M + C_s)}$$

③ Compare batch and CSTF



Batch

$$\frac{dC_x}{dt} = r_x \int_{C_x^0}^{C_x} \frac{dC_x}{r_x}$$



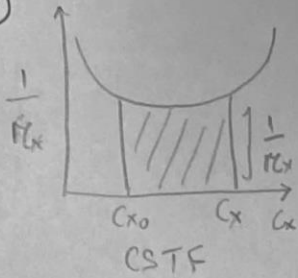
$$\tau_R = \frac{C_x - C_{x0}}{r_x}$$

Shanelle Bryant

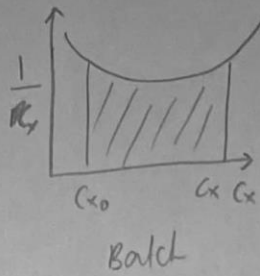
Exam #2

4/1/22

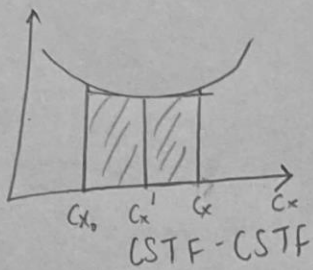
④



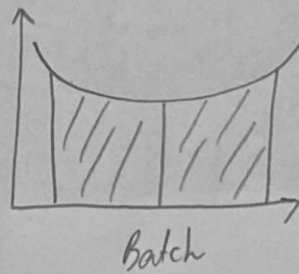
$$T = \frac{C_x - C_{x^0}}{R_x}$$



$$t = \int_{C_{x^0}}^{C_x} \frac{dC_x}{R_x}$$



$$A_1 = 10 - 1 + 10 + 2 = 17$$



BELOW AVERAGE

Jacquelyn Fuller

CHEG 4315

Test 2B

- ✓ 1). Derive the mass balance equations for cell growth and substrate consumption in an ideal CSTF. Ignore the lag and death periods.
- ✓ 2). Compare a series comprising a PFF and a CSTF for production of a chemical. Which combination of reactors has the smallest volume for same $C_A^0 - C_A$ range? Justify with a drawing and equations.
- 3). Compare a PFF and a CSTF for production of a chemical. Which reactor has the smallest volume? Justify with a drawing and equations.
- 4). Derive the mass balance equations for cell growth and substrate consumption in an ideal PFF. Ignore the lag and death periods.

1.)

Specific growth rate =

$$\mu = 1/x \frac{dx}{dt}$$

x = cell mass concentration (g/L)

t = time

growth kinetics = relation between specific growth rate & substrate

$$\mu = \mu_{\max} S / (K_s + S)$$

$$Y_{x/s} = dx/ds$$

$$\mu = \frac{Y_{x/s}}{x \frac{ds}{dt}} = Y_{x/s} q$$

gives Monod equation where m = ^{maintenance express} threshold substrate concentration

$$S = \frac{K_s D}{\mu_{\max} - D + S_{\min}}$$

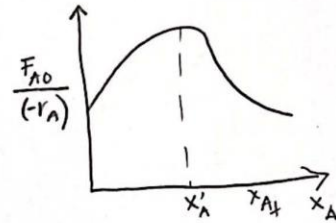
$$\mu = (\mu_{\max} + m) \left(\frac{S}{K_s + S} \right) - m$$

2.)

Option 1:

Desired conversion = x_{Af}

Conversion after 1st reactor = x'_{Af}



For PFR followed by CSTR

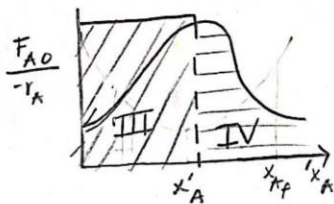


$$V_1 = I + II$$

$$V_1 < V_2$$

- For this option PFR follow by CSTR gives the smallest volume in this

For CSTR followed by PFR



$$V_2 = (III + IV)$$

-1.5

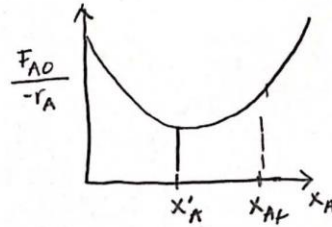
2)

(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) (15) (16) (17) (18) (19) (20) (21) (22) (23) (24) (25) (26) (27) (28) (29) (30) (31) (32) (33) (34) (35) (36) (37) (38) (39) (40) (41) (42) (43) (44) (45) (46) (47) (48) (49) (50) (51) (52) (53) (54) (55) (56) (57) (58) (59) (60) (61) (62) (63) (64) (65) (66) (67) (68) (69) (70) (71) (72) (73) (74) (75) (76) (77) (78) (79) (80) (81) (82) (83) (84) (85) (86) (87) (88) (89) (90) (91) (92) (93) (94) (95) (96) (97) (98) (99) (100)

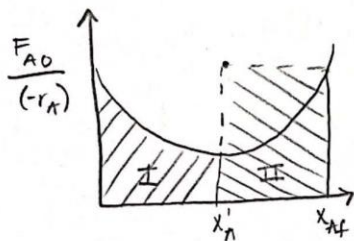
Option 2

desired conversion = x_{Af}

conversion after 1st reactor = x'_A



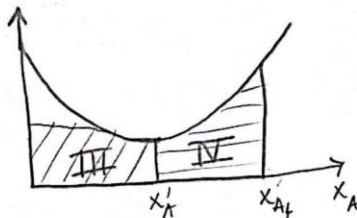
For PFR followed by CSTR



$$V_1 = (I + II)$$

- For this option
the CSTR followed
by the PFR gives
the smallest volume

For CSTR followed by PFR



$$V_2 = (III + IV)$$

*smallest volume of the combination of reactors
Shape of curve & conversion level desired.

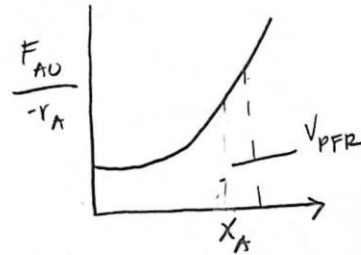
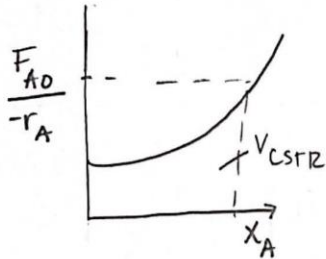
3.

CSTR

$$V = \frac{F_{A0} X_A}{-r_A}$$

PFR

$$V = \int_0^{X_A} \frac{F_{A0}}{-r_A} dX_A$$



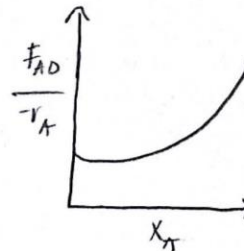
"Levenspiel plots"

- PFR is a smaller reactor given conversion when kinetics are positive order.

general Levenspiel plot

- as X_A , C_A ^{increases} decreases

$-r_A$ decrease so $\frac{F_{A0}}{-r_A}$ increases



4.) Mass balance is the same as CSTR

Specific growth rate =

$$\mu = \frac{1}{x} \frac{dx}{dt}$$

x = cell mass concentration (g/L)

t = time

growth kinetics = relation between specific growth rate & substrate

$$\mu = \mu_{max} S / (K_s + S)$$

$$Y_{x/s} = dx/ds$$

$$\mu = \frac{Y_{x/s}}{x} \frac{ds}{dt} = Y_{x/s} q$$

gives
Mond equation where m = ^{maintenance express} threshold substrate concentration

$$S = \frac{K_s D}{\mu_{max} - D + S_{min}}$$

$$\mu = (\mu_{max} + m) \left(\frac{S}{K_s + S} \right) - m$$

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Partial Exam III

TOPICS COVERED IN Partial Exam III

- 1. Transport Phenomena in Biological Systems**
- 2. Sterilization**

**BIOENGINEERING
SPRING 2022**

Problem Statement for Partial Exam III

CHEG 4315

Test A

- 1). Derive the equation describing the time variation of the amount of microbes during the sterilization process.
- 2). Propose an acceptable Δ value. Justify your choice with equations.
- 3). Draw a schematic of the two-layer model including the real and assumed concentrations profiles in both phases. Name all relevant concentrations.

ABOVE AVERAGE

Nina Patthammavong (38)

CHEG 4153

Test B

- 1). Write the equation for the global mass transfer coefficient from the liquid side (K_L).
- 2). Propose an acceptable final concentration of microbes. Justify your choice with equations.
Hint: use the design Δ value and $n^0 = 10^{10}$.
- 3). Draw a schematic of the two-layer model including the real and assumed concentrations profiles in both phases. Name all relevant concentrations.

10) Write the equation for the global mass transfer coefficient from the liquid side (k_L)

From Liquid side

$$k_g \Delta C_g = k_L \Delta C_L$$

$$k_g (C_g - C_{g,i}) = k_L (C_{L,i} - C_L)$$

$$H_{cc} = \frac{C_{L,i}}{C_{g,i}} \Rightarrow C_{g,i} = \frac{C_{L,i}}{H_{cc}}$$

$$k_g C_g - \frac{k_g C_{L,i}}{H_{cc}} = k_L C_{L,i} - k_L C_L$$

$$k_L C_{L,i} + \frac{k_g C_{L,i}}{H_{cc}} = k_g C_g + k_L C_L$$

$$C_{L,i} \left(k_L + \frac{k_g}{H_{cc}} \right) = k_g C_g + k_L C_L$$

$$C_{L,i} = \frac{k_g C_g + k_L C_L}{k_L + \frac{k_g}{H_{cc}}}$$

$$J_L = k_L (C_{L,i} - C_L)$$

$$= \frac{k_L k_g C_g + k_L^2 C_L}{k_L + \frac{k_g}{H_{cc}}} - k_L C_L$$

$$= \frac{k_L k_g C_g + \cancel{k_L^2 C_L} - \cancel{k_L^2 C_L} - k_g k_L C_L / H_{cc}}{k_L + k_g / H_{cc}}$$

$$= \frac{k_g k_L (C_g - C_L / H_{cc})}{k_L + k_g / H_{cc}} \quad \text{--- } k_L$$

$$J_L = k_L (C_g - C_L / H_{cc})$$

2.1 Propose and acceptable final concentration of microbes

Use the design Δ value and $n_0 = 10^{10}$

$$\frac{dn}{dt} = -k_d n$$

$$\int_{n_0}^n \frac{dn}{n} = -k_d \int_0^t dt$$

$$\ln \frac{n}{n_0} = -k_d t$$

$$-\ln \frac{n_0}{n} = -k_d t$$

$$\ln \frac{n_0}{n} = k_d t \Rightarrow n = n_0 e^{-k_d t}$$

$$\Delta = \ln \frac{n_0}{n} \approx 30.$$

$$\Delta = \ln \frac{10^{10}}{10^{-3}} = 29.9 \approx 30 \text{ it's satisfied.}$$

n is very small because microbes can grow again.

$$n_0 = 10^{10}$$

$$k_d = \frac{1}{100} \text{ h}^{-1}$$

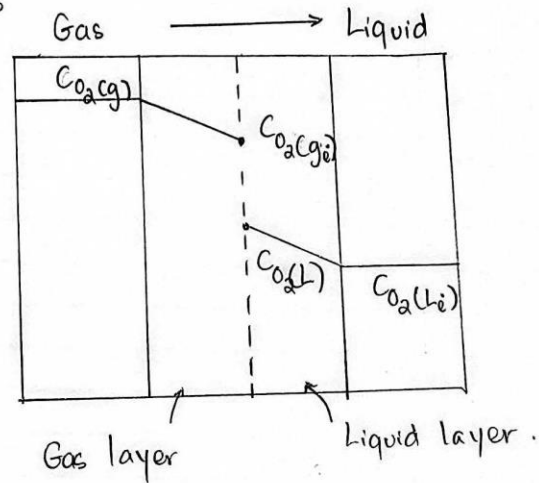
Find $t=9$ for safe operation

$$\Delta = k_d t$$

$$t = \frac{\Delta}{k_d} = \frac{30}{100 \text{ h}^{-1}} = 0.3 \text{ h} \times \frac{60 \text{ min}}{1 \text{ h}} = 18 \text{ min}$$

$$n = \frac{10^{10}}{10} e^{-18/100}$$

Q.1 Draw a Schematic of the two-layer model including the real and assumed concentration profiles in both phases. Name all relevant concentrations



3

Assume $C_{O_2(g)}$ = Gas Concentration of O_2

$C_{O_2(g,i)}$ = Gas Concentration of O_2 at interface

$C_{O_2(l)}$ = Liquid Concentration of O_2

$C_{O_2(l,i)}$ = Liquid Concentration of O_2 at interface

AVERAGE

Chad Grader

CHEG 4153

Test B

- 1). Write the equation for the global mass transfer coefficient from the liquid side (K_L).
- 2). Propose an acceptable final concentration of microbes. Justify your choice with equations.
Hint: use the design Δ value and $n^0 = 10^{10}$.
- 3). Draw a schematic of the two-layer model including the real and assumed concentrations profiles in both phases. Name all relevant concentrations.

#1 $k_g \gg k_L$ we can assume no resistance on gas phase

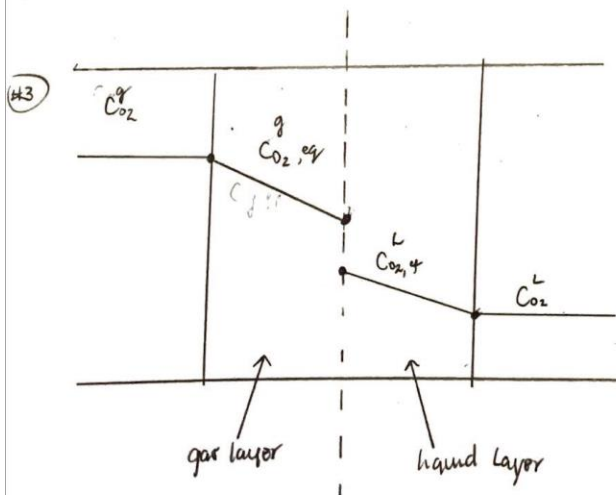
Liquid side

$$\frac{1}{K_L} = \frac{1}{k_L} + \frac{H}{k_g} \approx \frac{1}{k_L} \Rightarrow K_L = k_L$$

#2 Since $n^0 = 10^{10}$; $\ln \frac{n^0}{n} = \Delta = 30 \Rightarrow$

$$n = \frac{10^{10}}{e^{30}}$$

n , very small since microbes can grow again rapidly



$C_{O_2}^g$ = gas concentration of O_2

$C_{O_2,g}^i$ = gas concentration at the interface

$C_{O_2}^L$ = liquid concentration of O_2

$C_{O_2,L}^i$ Liquid concentration at the interface

BELOW AVERAGE

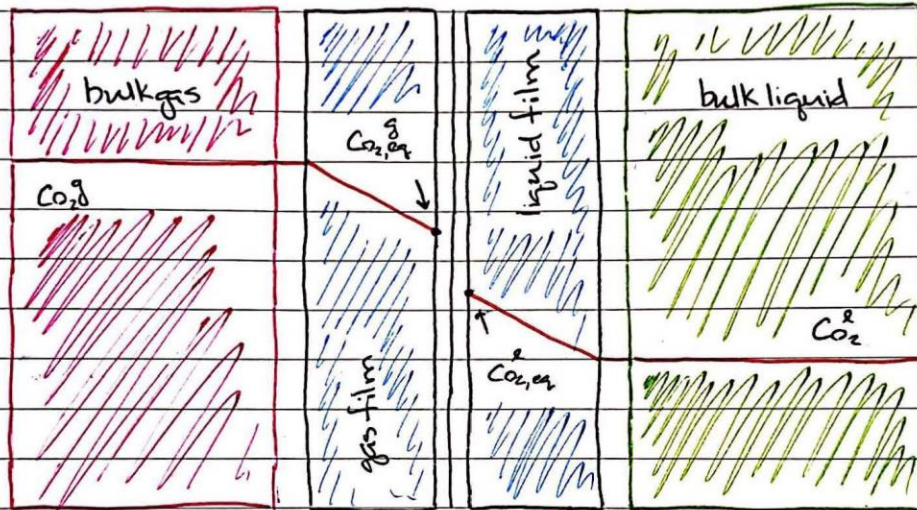
Test 3B

Caleb Myers

1. Global mass transfer coefficient from liquid side (K_L):

$$N_{O_2} = K_L A_{GL} \left[\frac{CO_2^g}{H} - CO_2^L \right]$$

3. Interface



CO_2^g = gas concentration of O_2

CO_2^L = liquid concentration of O_2

$CO_{2,eq}^g$ = gas concentration at the interface

$CO_{2,eq}^L$ = liquid concentration at the interface

2. $\ln \frac{n_0}{n} = \Delta \approx 10$

$$e^{10} = \frac{n_0}{n}$$

$$n = \frac{n_0}{e^{10}}$$

* n is an extremely small value because of regenerative microbes

**BIOENGINEERING
SPRING 2022**

Title of Assignment: Final Exam

TOPICS COVERED IN Final Exam

- 1. Chemicals of Life**
- 2. Kinetics of Enzymatic Reactions**
- 3. Microbial Life Cycle**
- 4. Bioreactor Design**
- 5. Transport Phenomena in Biological Systems**
- 6. Sterilization**

**BIOENGINEERING
SPRING 2022**

Final Exam Sample Questions

CHEG 4315

Final A

1). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

2). Write the generic formula for monosaccharides (simple sugar). Monosaccharides present two kind of cyclic structures. How many atoms does the cycle have?

3). Derive the mass balance equations for cell growth and substrate consumption in a batch reactor. Ignore the lag period and use a death period.

4). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.01 \text{ mol L}^{-1}, v_{\max} = 5 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

5). Derive the global mass transfer coefficient from the liquid side (K_L) assuming that there is significant resistance in both phases.

$$\text{Use: } H = \frac{C_{i,eq}^g}{C_{i,eq}^L}$$

ABOVE AVERAGE

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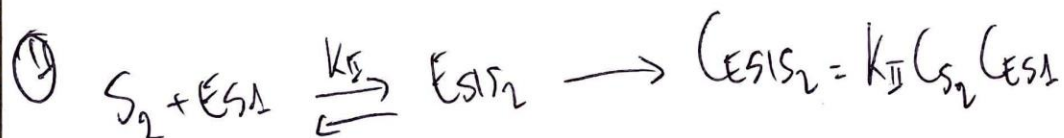
$$\text{Use: } H = \frac{c_{Leq}^g}{c_{Leq}^L}$$

1) The equation of the Enzyme is

$$C_E^0 = C_E + C_{ES1} + C_{ES1S2}$$

We know that

$$\textcircled{I} \quad K_I = \frac{C_{ES1}}{C_{S1} \cdot C_E} \Leftrightarrow \boxed{C_E = \frac{C_{ES1}}{K_I \cdot C_{S1}}}$$



Then the equation of the Enzyme becomes

$$C_E^0 = \frac{C_{ES1}}{K_I \cdot C_{S1}} + C_{ES1} + K_{II} C_{S2} C_{ES1}$$

$$= C_{ES1} \left(\frac{1}{K_I \cdot C_{S1}} + 1 + K_{II} C_{S2} \right) = C_{ES1} \left(1 + \frac{1}{K_I \cdot C_{S1}} + K_{II} C_{S2} \right)$$

$$= C_{ES1} \left(\frac{1 + K_I C_{S2} + K_I K_{II} C_{S1} C_{S2}}{K_I \cdot C_{S1}} \right)$$

Then

$$C_{ES1} = \frac{(K_1 \cdot C_{S1}) C_E^0}{1 + K_1 C_{S1} + K_1 K_2 C_{S1} C_{S2}}$$

Then

$$R_p = K_p C_{ES1} = K_p \frac{C_E^0 (K_1 C_{S1})}{1 + K_1 C_{S1} + K_1 K_2 C_{S1} C_{S2}}$$

$$R_p = K_p C_{ES1} = K_p \frac{C_E^0 (K_1 C_{S1})}{1 + K_1 C_{S1} + K_1 K_2 C_{S1} C_{S2}}$$

2) the generic formula is



The cycle has

a) Piranose with 5C and 1O

b) Furanose with 4C and 1O

3) Bath (exponential)

$$\cancel{dX} - \cancel{dX} + \text{Gen} = \text{Acc}$$

ADDAFTER

$$R_x V_R = \frac{dC_x}{dt} = \mu C_x V_R = \frac{U_{\max} C_s C_x}{K_s + C_x} V_R - b C_x$$

$$Y_{x/s} = - \frac{dC_x}{dC_s}$$

$$\Rightarrow dC_x = - Y_{x/s} dC_s$$

then

$$\frac{dC_s}{dt} = - \frac{U_{\max} C_s C_x}{Y_{x/s} (K_s + C_x)}$$

No Death

4) we have $K_M = 0.01 \text{ mol} \cdot \text{L}^{-1}$, $V_{\max} = 5 \text{ mol} \cdot \text{L}^{-1} \cdot \text{min}^{-1} = R_{\max}$

The Michaelis-Menten equation is

$$V = \frac{V_{\max} [S]}{K_m + [S]} \Leftrightarrow \frac{1}{V} = \frac{K_m + [S]}{V_{\max} [S]}$$

$$\Leftrightarrow \frac{1}{V} = \frac{K_m}{V_{\max} [S]} + \frac{[S]}{V_{\max} [S]} = \frac{K_m}{V_{\max}} \cdot \frac{1}{[S]} + \frac{1}{V_{\max}}$$

Then

$$C_{gi} = \frac{h_g G + h_c C}{k_L/H_c + h_g}$$

2nd step: Replace C_{gi} in $A J^g$

$$J = h_g [G - C_{gi}] = h_g G - h_g \frac{(h_g G + h_c C)}{k_L/H_c + h_g}$$

$$= \frac{h_g G (k_L/H_c + h_g) - h_g^2 G - h_g h_c C}{(k_L/H_c + h_g)}$$

$$= \frac{h_g h_c G/H_c + h_g^2 G - h_g^2 G - h_g h_c C}{(k_L/H_c + h_g)}$$

$$J = \frac{h_g h_c G/H_c - h_g h_c C}{k_L/H_c + h_g}$$

$$J = \left(\frac{k_g \cdot k_L}{k_L/H_c + k_g} \right) \left(\frac{C_g}{H_c} - C_l \right)$$

Global Mass Transfer Coefficient

$$\dot{m}_2 = K_L A_{GL} \left(\frac{C_{O_2}^g}{H} - C_{O_2}^L \right)$$



AVERAGE

8.6

CHEG 4153
Final C

- 1). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

- 2). Which are the main functional groups of amino acids? How many structures proteins have? Do not describe them.

- 3). Write the global mass transfer coefficient from the gas side (K_G) assuming that there is significant resistance in both phases. Which is the value of K_G if there is no liquid phase resistance?

Use: $H = \frac{c_{i,eq}^g}{c_{i,eq}^L}$

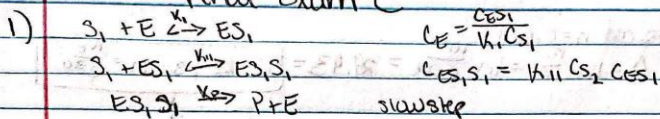
- 4). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.02 \text{ mol L}^{-1}, v_{\max} = 12 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

- 5). Propose an acceptable ∇ (del factor) value for design purposes. Justify your choice with equations.

Final Exam C



$$C_E^0 = C_E + C_{ES_1} + C_{ES_1 S_1}$$

$$C_E^0 = \frac{C_{S_1}}{K_1 C_{S_1}} + C_{S_1} + K_{11} C_{S_1} C_{S_1} E$$

$$r_p = C_{ES_1 S_1} k_2$$

$$\left(K_{11} = \frac{C_{ES_1 S_1}}{C_{ES_1} C_{S_1}} \right) \rightarrow \text{substitute into } C_E^0$$

$$C_E^0 = \frac{C_{S_1} k_2}{K_1 K_{11} C_{S_1} C_{S_1}} + \frac{C_{S_1} k_2}{K_1 C_{S_1}} + C_{S_1} k_2$$

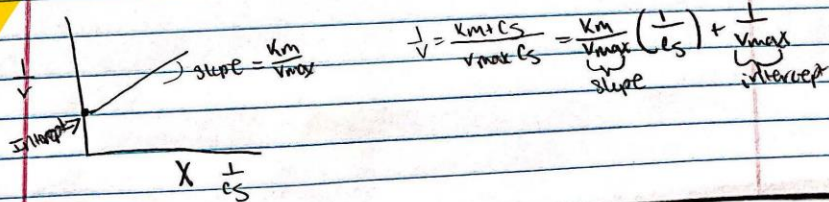
$$C_E^0 = C_{S_1} k_2 \frac{(1 + K_1 C_{S_1} + K_{11} C_{S_1}^2)}{K_1 K_{11} C_{S_1} C_{S_1}}$$

$$r_p = k_2 C_{S_1} k_2 = \frac{k_2 C_E^0 K_1 K_{11} C_{S_1}^2}{1 + K_1 C_{S_1} + K_{11} C_{S_1}^2}$$

2) The main functional groups are amine ($-NH_2$) and carboxyl ($-COOH$).
 There are four structures; primary, secondary, tertiary and quaternary.

3) $K_a = \frac{C_{H^+} C_{A^-}}{C_{HA}}$
 $No_2 = K_g A_g - l (C_{O_2}^g - C_{O_2,eq}^g)$
 $No_2 = K_g A_g - l (C_{O_2}^g - H C_{O_2}^g)$
 $(K_g = No_2 / A_g - l (C_{O_2}^g - C_{O_2}^g)) \Rightarrow K_g = \frac{No_2}{A_g - l (C_{O_2}^g - C_{O_2}^g)}$
 If no lag phase, $K_a = 0$

4. $K_M = 0.02 \text{ mol/L}$ $V_{max} = 12 \text{ mol/L} \cdot \text{min}$ slope & int. = ?
 $\text{slope} = K_M / V_{max} = 0.02 \text{ mol/L} / 12 \text{ mol/L} \cdot \text{min} = 0.0016 = 1.002$
 $\text{intercept} = 1 / V_{max} = 1 / 12 \text{ mol/L} \cdot \text{min} = 0.08 \frac{\text{L} \cdot \text{min}}{\text{mol}}$



5) For desired $n=0.001$

$$\Delta = \ln \frac{n_0}{n} = \ln \frac{10^{10}}{0.001} = 29.93 = 30 \approx \lambda, \text{ so } n = \frac{n_0}{e^{30}}$$



BELOW AVERAGE

CHEG 4153

Final C

1). Assume that the following sequence describes the reaction of one substrate catalyzed by one enzyme:



Derive the kinetic equation using the Michealis-Menten procedure.

2). Which are the main functional groups of amino acids? How many structures proteins have? Do not describe them.

3). Write the global mass transfer coefficient from the gas side (K_G) assuming that there is significant resistance in both phases. Which is the value of K_G if there is no liquid phase resistance?

Use: $H = \frac{C_{Leq}^g}{C_{Leq}^L}$

4). A substrate is converted to a product by the catalytic action of an enzyme. Assume that the Michaelis-Menten kinetic parameters for this enzyme reaction are:

$$K_M = 0.02 \text{ mol L}^{-1}, v_{\max} = 12 \text{ mol L}^{-1} \text{ min}^{-1}$$

Calculate the slope and the intercept of a Lineweaver-Burk plot ($1/r$ vs $1/C_s$). Justify.

5). Propose an acceptable ∇ (del factor) value for design purposes. Justify your choice with equations.

Bioeng. - Final Exam

1. $\frac{d[P]}{dt} = k_p[ES_1]$

$$\frac{d[ES_1]}{dt} = 0 = k_1[S_1][E] - k_{11}[S_1][ES_1] - k_p[ES_1]$$

$$[ES_1] = \frac{k_1[S_1][E]}{k_{11}[S_1] + k_p}$$

$$[S_1] \approx [S_0] \text{ and } [S_0] \gg [E_0]$$

$$[ES_1] = \frac{k_1[S_0]([E_0] - [ES_1])}{k_{11}[S_1] + k_p}$$

$$[ES_1] = \frac{k_1[S_0][E_0]}{k_{11}[S_0] + k_p + k_1[S_0]}$$

$$= \frac{[S_0][E_0]}{[S_0] \left[\frac{k_{11}}{k_1} + 1 \right] + \frac{k_p}{k_1}}$$

$$= \frac{[S_0][E_0]}{[S_0] \left[\frac{k_{11}}{k_1} + 1 \right] + \frac{k_p}{k_1}}$$

$$[ES_1] = \frac{[S_0][E_0]}{\left[\frac{k_{11}[S_0] + k_p}{k_1} \right] + [S_0]}$$

$$\left[\frac{d[P]}{dt} \right]_0 = r_0 = \frac{k_2[E_0][S_0]}{\left[\frac{k_{11}[S_0] + k_p}{k_1} \right] + [S_0]}$$

-1.5

2. There are four functional groups present in amino acid, carboxyl group, hydrogen, amine group, and R-group. But main functional groups are amine and carboxyl group.

Protein has 4 structures - Primary, secondary, tertiary, and quaternary.

3.

4. $\frac{1}{v} = \frac{K_m}{V_{max}} \cdot \frac{1}{S} + \frac{1}{V_{max}}$

slope: $\frac{K_m}{V_{max}} = \frac{0.02 \text{ M}}{12 \text{ mol min}^{-1}} = 0.0016 \text{ min}$

$y_{int}: \frac{1}{V_{max}} = \frac{1}{12} = 0.083 \text{ min}^{-1}$

5. $\ln \frac{n_0}{n} = \Delta \approx 30 = n = n_0 / l^{30}$

n is very small because microbes can grow again. ✓

