G U I D E   F O R   S U C C E S S
ABE 304: Bioprocess Engineering Laboratory

Process Overview
ABE 304: Bioprocess Engineering Laboratory

Process Overview

The overall goal of ABE 304: Bioprocess Engineering laboratory will be to produce and encapsulate Xanthan gum from *Xanthomonas campestris*. To accomplish this goal, the course is divided into six individual lab modules, which are ordered in a fashion that they might be arranged in an industrial production setting. Figure 1 displays the general process overview for this course.

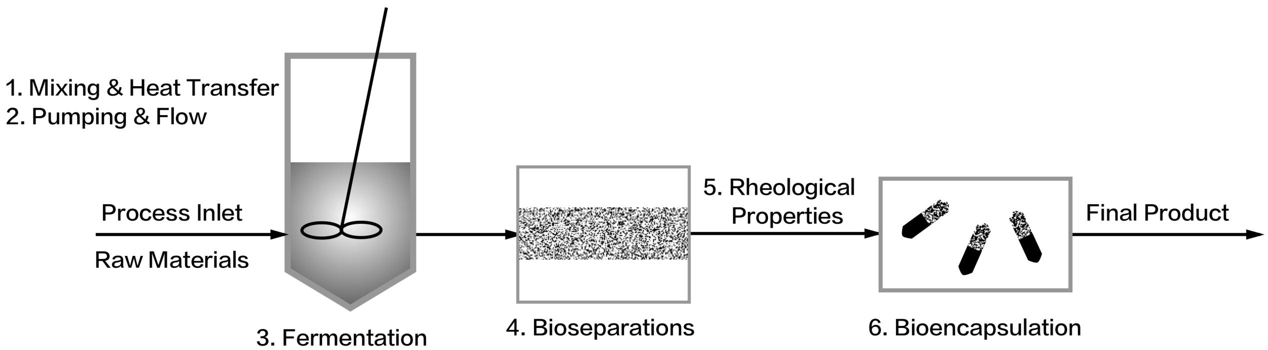

Figure 1: Process diagram for the six lab modules that will be covered in ABE 304.

A more in-depth description and purpose for each module is as follows:

1. **Mixing and Heat Transfer** This module will allow for calculation of heat transfer coefficients and will give insight into the time needed for full mixing and heat transfer properties during fermentation.	4. **Bioseparations for XG Concentration** After fermentation, the XG will be present in solution along with the bacterial cells. To enable encapsulation, the XG must be separated from the broth. This module will give hands-on separation experience using ultrafiltration techniques.
2. **Pumping and Product Flow** The product will need to be transported throughout the different stages of the process. This module is designed to give an understanding of the amount of energy and power is required to pump the fluid. This module will also give the user insight into the effect of pipe diameter on the pump requirements.	5. **Rheological Properties of Biofulids** The rheological properties of a biological substance must be examined to determine if there will be additional energy requirements for pumping or for heat transfer. The rheological properties can also be used for quality control purposes.
3. **Fermentation for XG Production** The Xanthan Gum (XG) will be produced during fermentation of *Xanthomonas campestris*. XG is produced intracellularly and then ruptures the cell wall to become an extracelluar product. Fermentation will first be performed on a small lab scale to understand the kinetic parameters and will then be scaled up to determine the effect of volume on the production rate.	6. **Bioencapsulation of XG** The final step in the process is bioencapsulation. For final product use, the XG is encapsulated. This module will allow for investigation into concentration and temperature conditions for product encapsulation.

Lab Safety
ABE 304: Bioprocess Engineering Laboratory

Safety Guidelines

General Recommendations

1. Pay attention to your surroundings! Don't endanger yourself or others by being careless.
2. Don't be afraid to ask questions! Your instructors and TAs are well versed in lab safety, and we would rather answer questions upfront than deal with safety issues later.
3. Do not eat, drink, or apply cosmetics in the lab.
4. Always wear appropriate personal protective equipment (PPE) while in the lab. This means long pants, **<u>NO sleeveless shirts</u>**, and close-toed shoes always and sometimes lab coats, safety glasses, or gloves. If you are dressed inappropriately for working in the lab, you will be *dismissed*. PPE, such as gloves and safety glasses, will be provided as required.
5. Know the location of the eyewash station and safety showers in case of emergencies.
6. Always be aware of the fire and weather protocol in the building where the lab is located.
7. Read/study the MSDS of any substance you are working with, especially if you do not have any previous experience with using it.
8. Keep in mind what the appropriate storage for all substances, especially flammable materials.
9. If you work with pressure fluids or lines (air, propane, nitrogen, etc.), know how to open and close the valves and when opening them do it <u>slowly</u>.

Mixing

PPE Required: Eyewear, long pants, non-slippery close-toed shoes, hair restraints, and lab coats

- You will be working with HOT steam (120°C-150°C or 250°F-300°F). Be careful at all times. Use the appropriate insulated gloves to handle the valves.
- Do not get too close to the vessel because the jacket will be at the steam temperature, and you will burn yourself.
- Be aware of the location of the steam trap because there will be steam coming out.
- Do not be afraid of the noise that the steam causes, especially when purging the system; it is normal and is caused by sublimation-condensation due to the contact of the two water phases (liquid-steam).
- During the heating, the mix inside will get hot; stay at a prudent distance in case of a spill. If the system behaves unexpectedly close the steam and turn the agitation off.
- During the cooling process, water will flood the floor; walk carefully.
- If you have a spill of the CMC solution, wash it immediately with the hose because it will make the floor even more slippery.
- The food plant has other equipment that might be in operation during the lab. Always stay at a prudent distance.

Flow

PPE Required: Wear long pants, close-toed shoes

- Do not activate a pump if there is no fluid to pass through (valves closed). This can damage the pump and eventually cause some cavitation. Cavitation is when vapor zones are formed within the liquid (bubbles), and these can implode and impact the pump, causing cracks.
- The valves in the piping system are "heavy duty." Nevertheless, open and close them gently. If one of them is damaged during your experiment, you and your classmates' experiments can be jeopardized.
- Do not operate the pumps with all of the valves closed for a long time. This will cause undue stress at the junctions of the piping system that could result in leakages.

Fermentation
PPE Required: Eye protection, long pants and close-toed shoes. Lab coats, goggles, and gloves will be provided when needed.

- Make sure the close-toed shoes you choose to wear have good soles.
- Gloves and safety glasses will be provided. Safety glasses need to be worn at all times unless you are instructed that you may remove them.
- Pay attention when instructed on how to use pipettors, and ask for help if you need it.
- Treat cells and chemicals with care. Do not handle solutions or testing equipment without gloves.

Bioseparations
PPE Required: Wear long pants, close-toed shoes. Lab coats, goggles, and gloves will be provided when needed.

- All biological entities will be BioSafety Level 1. Therefore, they can be handled at an open bench. Gloves are required.
- Pay attention when instructed on how to use pipettors, and ask for help if you need it.
- Treat proteins, equipment, and chemicals with care. Do not handle solutions or testing equipment without gloves.
- When working with biological entities, pay special attention to possible sources of contamination. Pipettor tips should not come in contact with the bench top or other contaminating surfaces.
- Absolutely no food or drink is allowed. Do not chew gum, apply cosmetics, or handle contacts. Avoid touching your eyes or mouth.

Rheology
PPE Required: Wear long pants, close-toed shoes and protective eyewear.

- The viscometers we will be using are sensitive instruments. Treat them with caution when using them to avoid damaging them.
- Preparation of gelatin solutions will require the use of a hot plate. Use a hot pad or insulated gloves when handling freshly prepared gelatin solutions.
- Wear gloves when preparing the gelatin solution. Gloves will be provided.
- Do not touch moving parts of the viscometers when they are operating.

Bioencapsulation

PPE Required: Wear long pants, close-toed shoes. Lab coats, goggles, and gloves will be provided when needed.

- When handling acids, wear a lab coat, gloves, and goggles. Always add acid to water; never add water to acid when diluting an acid.
- Take note of the locations of eyewash stations and shower in the lab.
- Pay attention to when the lab manual instructs you to work in the chemical hood. Keep the hood sash at the designated level.
- All biological entities will be BioSafety Level 1. Therefore, they can be handled at an open bench. Gloves are required.
- Washing your hands should always be the first and last thing you do when you enter and leave the lab.
- Absolutely no food or drink is allowed. Do not chew gum, apply cosmetics, or handle contacts. Avoid touching your eyes or mouth.
- DO NOT touch the phone, doorknobs, sink handles, etc. while wearing gloves. Remove gloves BEFORE leaving the lab.
- Loosen all caps on bottles before microwaving any liquids.
- Note all signage on doors, and DO NOT enter any laboratory in the building other than your designated work areas.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory

General Information and Suggestions for Technical Writing

- In this course, you will need to submit both formal and memo style reports. You will also write and submit both individual and group reports. The schedule for the report type for each lab module is listed in your syllabus.
- Be concise in your writing. Say what needs to be said but no more. Do not use three sentences when two will do. Avoid being overly verbose.
- Write your reports with the attitude that they will be something you submit for a job assignment.
- Do not use phrases like "The purpose of this lab was…" or "For this lab we…"
- Do not use titles like "Rheology Lab". Be descriptive, but keep it concise.
- Write with a level of complexity that is consistent with your technical background. You have acquired a lot of knowledge in your studies. Show us what you know.
- Write for an audience that also has a technical background but is most likely not entirely familiar with your experiment.
- All variables and uncommon terms need to be defined. All acronyms need to be spelled out at least once. However, common terms like psi or mL do not need to be defined.
- A considerable amount of judgment must be exercised when writing your reports: the ideas to be discussed and how best to organize these; the detail to be provided; the figures and tables to be shared; the comparisons with theory or other work, etc. It will take a considerable amount of time to make these judgements.
- *Use your own words* to avoid plagiarism. It is not difficult to recognize when material has been copied and this will be heavily penalized. Do not use direct quotes from your sources; synthesize what you read and put it into your own words.
- Use references where needed. If you state a fact from a source, you need to cite the source.
- Prepare tables, graphs, and figures very carefully. Label all visuals appropriately. See the section on **Report Visuals and Data Display**.
- Cite references appropriately. Look in a textbook or journal article for style examples. See section on **References** for additional guidance.
- *Make your report look good*. Be neat and well organized. Pay attention to formatting. Use headings and sub-headings to let the reader know what they will be reading.
- Write in third person and use past tense. You are explaining what you have done, not what you intend to do.
- Do not begin a sentence with a number (i.e. 10 mL of water was poured into a beaker). Numerals less than ten should be spelled out – unless it is a measured or quantitative value (i.e. Five pressures were measured ranging from 10 psi to 25 psi).
- Include the leading zero in a measured value (i.e. 0.75 mL, not .75 mL)
- Avoid using contractions.
- Use superscripts and subscripts as needed.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory

Report Sections

- All reports must have:
    - **Beginning**
        - Goals and introduction
        - Background
            - Basic principles
            - Related models and theories
    - **Middle**
        - Nature of experiment
            - Equipment used
            - Procedures
            - Data to be obtained
    - **End**
        - Data analysis
        - Results obtained
        - Error analysis
    - **Major conclusions**
    - **Nomenclature**
    - **References**
    - **Appendix**
        - Sample calculations
        - Extraneous, but helpful data or tables

Report Formatting

All reports will be written in Times New Roman 11 pt. font. All pages will be formatted to have 1" margins. The text should be left justified with a line spacing of 1.5. Line spacing may be single for Table and Figure captions.

Report Final Check

- After writing your report, ask yourself the following questions:

    1. Does the report have something meaningful to say?
    2. Is the report in a format acceptable to the reader?
    3. Are the ideas organized in a way that makes it easy for your reader to understand?
    4. Have you used an appropriate level of sophistication in your writing?
    5. Does the report look good?
    6. Have you made effective use of figures and tables?

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory

Formal Reports

Formal reports are divided into sections, which have the following distinctive headings:

1.	Title Page	(5 points)
2.	Summary	(10 points)
3.	Introduction	(5 points)
4.	Theory/Basic Principles	(10 points)
5.	Experimental	(10 points)
6.	Presentation and Discussion of Results	(20 points)
7.	Conclusions and Recommendations	(10 points)
8.	Nomenclature	(2.5 points)
9.	Literature Cited	(2.5 points)
10.	Appendices	(5 points)
	Overall format of the report	(20 points)

Sections 2, 3, 8, and 9 are to begin on new pages. ***You do need to use these exact headings for your report to guide your audience as to what section they are reading***. The following provides some guidance to the content of the various sections. These are not meant to be absolute, but are common in practice.

Title page
The title page clearly identifies the nature of the report and who performed the work. Choose a descriptive title. For example, “Effect of Pump Configuration on Flow of Water Through a Piping System” is better than simply, “Pumps and Piping Lab Report”. The date of the report submission should be included on this page. Write out your names (take credit for your work).

Summary
The summary is intended to completely, yet briefly, inform the reader of the basic nature and major implications as a one-page report on the major aspects of the work. This section must be one full page. This section should <u>briefly</u> state what was done and how, what the principle results were, and the conclusions that were drawn. It should be able to stand *ALONE*. References to other parts of the report should not be used in the summary. In a professional setting, the summary would be used to determine if the report was worth reading in its entirety.

Introduction
The summary in intended to stand alone; the main body of the report should have an introduction as if the summary were not included. The introduction should briefly reveal the scope and relevance of the investigation, and broadly what techniques were used. No mention of the results or conclusions will appear here; these will be discussed later.

Theory and Basic Principles
A discussion of the theory or basic principles involved with this project is appropriate to include. Assume your reader is technically proficient, but not necessarily acquainted with the specific background of your work. This section should provide enough detail so that the reader will understand the basis for the laboratory work and the analysis of the data. For example, the reader will know what a heat transfer coefficient is, but you will need to explain how it relates to your experiment. Use equations when needed and define the symbols. Use references for your equations and state conditions at which they are valid.

Experimental

Use this section to explain the experimental equipment and procedures. Explain major items using computer drawn renderings of the equipment or process to help the reader visualize the experiment. **A computer drawn rendering must be included.** Often flow sheets or line drawings are sufficient. Do not get too bogged down in exhaustive detail for familiar procedures. For example, indicating that "Product concentration was determined by titrating samples from the reactor with standard acid" is a sufficient description. You don't need to say that a 10 mL sample was taken and placed in a 250 mL Erlenmeyer flask then titrated with 0.05N HCl using Bromothymol blue as the indicator. However, be sensitive to the fact that in certain instances procedural details form a key part of the information to be conveyed in the report. In most instances, give general run down of what was performed, what was measured, and in what sequence. Highlight the important procedural items. Aspects such as how many runs were made, how conditions were varied, what ranges of variables were investigated, etc. are of interest in this section. Do not write as a step-by-step account.

Presentation and Discussion of Results

This section is the heart ♥ of the report; the place where you demonstrate the value of what you have done, including your awareness of the implications of the work.

The "presentation" aspect refers to the display of results in text, graphical, tabular, or other form. "Discussion" refers to a written assessment of the significance of the results. In presenting results, choose the form that is most effective and allows the reader to grasp the nature of the results quickly and accurately. Look at textbooks, journals, or scientific writing for examples. Graphs are often preferred because they very quickly convey the information to your reader. A trend is more quickly spotted in a graph rather than in a table. In your text, introduce the graph or table you wish to discuss. For example: "Figure 1 displays the effect of carrier gas flow rate on the retention times for benzene and acetone." Then discuss the major features of the figure – are the trends as expected, do the results agree with theory or with data of other investigators, etc. After sufficient elaboration, move on to the next figure or table. In some cases, you may wish to present and discuss two or three closely related tables or figures together. Use appropriate significant figures (SigFigs) in presenting numerical results. At the end of the section, a discussion of the results taken collectively is often appropriate.

When discussing results, assess them realistically. Do not force your data to fit the theory. Examine sources of experimental error critically and discuss these if they affect the results significantly. Were the assumptions made in developing theory fulfilled experimentally? If not, assess the effect this would have on agreement of experimental result and theory. If data scatter is so great that no correlation is possible, include this finding in your report. But also try to determine why the data scatters. Do not develop unwarranted conclusions based on pre-conceived notions of what the results should be. On the other hand, if your data is good, or the results reveal important phenomena, or agreement with the theory is excellent; highlight your success.

Conclusions and Recommendations

Major conclusions drawn from the experiment sometimes are listed 1, 2, 3, etc. following a simple introductory statement. Alternately, a conventional narrative style may be used. A list of recommendations for experimental alternatives should be included.

Nomenclature

In the nomenclature section, symbols used in the report are defined. These are listed alphabetically, Arabic letters first, followed by Greek symbols and subscripts and superscripts. Units are provided for the convenience of the reader.

Nomenclature Example:

A_C	cross sectional area	[m^2]
A_S	surface area	[m^2]
Re	Reynolds number	[-]
t_R	retention time	[s]
μ	viscosity	[kg/m•s]
ρ	density	[mg/mL]

Literature Cited

References to the literature should be cited in the body of the report using a the author last name and year of publication enclosed in parentheses. In this case, the references should be listed alphabetically within the Literature Cited. Refer to the section on *References and Citations* for additional guidance.

Appendices

Long derivations and/or other background material that is not essential to the body of the report should be placed in an appendix. The essentials are placed in the body and the reader referred to the appendix for details. Tables of data and calibration curves usually are place in an appendix, as in a sample calculation, which illustrates how the raw data were used to obtain the final results. The appendices are given descriptive headings to separate different types of material. The entirety of your data tables should **NOT** be included in the appendix. If your data is earth shatteringly brilliant, we will seek out your full data tables.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Form Example for a Title Page</u>

Final Report

EFFECT OF PUMP FORMATION ON THE PRESSURE DROP IN DIFFERERING PIPE CONFIGURATIONS

A.M. Early

Bioprocess Engineering Laboratory
Agricultural & Biological Engineering
West Lafayette, IN 47907

April 7, 2017

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory

Memo Style Reports

This type of report is intended to communicate fully the results of the work completed without providing the exhaustive detail that normally accompanies a more formal report. The physical style is that of a long memorandum or business letter and makes use of a continuous narrative rather than sections with formal headings. The report usually runs two to three pages in length with tables, figures, data, and sample calculations included. Your report should include up to three key figures in the body of the report; other pertinent figures can be placed in the appendix. An example cover page is included. The following sequence of development is suitable:

1. Brief introduction and orientation to the work carried out (10 points); a concise description of the scope of the work; a summary of the relevant background *if needed*. The relevant theory and references to other work can be integrated with a presentation of the results.
2. A brief description of the experimental apparatus and methods used (10 points); use a computer drawn sketch to help explain. The sketch can be placed in the appendix.
3. Present and discuss results (30 points). Use figures and tables as appropriate. Provide comparisons to theory or experimental results of others. Assess the significance of the results. Do they agree with the literature sources? What sources of error exist?
4. Complete the text by briefly summarizing the major conclusions (10 points).
5. Append (20 points): a list of citations, nomenclature, sample calculations, details necessary to supplement the text.

Overall format of the report (20 points)

This type of report is often useful if your boss or supervisor needs to quickly understand your work when going into a meeting or conference. This style of report can help continue funding on your project if the information is concisely worded.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Form Example for a Technical Memorandum</u>

Bioprocess Engineering Corporation
Agricultural & Biological Engineering
West Lafayette, IN 47907

To: I.N. Tegral

From: A.M. Early

Date: April 7, 2017

Subject: Pump Formation Effects on the Pressure Drop in a Length of Pipe

Pump formation plays a key role in the pressure drop in a length of pipe. In this work, the effect of the pump placement – either in series or in parallel – was studied to determine how the pressure changed over the length of the connected pipe. An extensive series of experiments was conducted and the results were compared to several theoretical models.

Pressure drop often occurs as the length of pipe increases. The configuration of the pumps can greatly affect how much the pressure decreases over the pipe length. As a result of the pump configuration, …

(The body of the memorandum continues – usually for several pages. Appendices are attached).

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Formatting for Visuals</u>

Report Visuals and Data Display

Figures

- Graphs
- Sketches
- Schematics
- Process flow diagrams

The caption for a figure should be placed below the figure and should be centered. The caption should be descriptive enough that the reader can understand the figure without referring to the text. All figures should be referenced in the text before they appear in your report. An example, Figure 2 is included on this page. Notice that in the sentence the first letter of the word *FIGURE* is capitalized when referring to a figure. The font for the figure caption should be 1 point smaller than the font for the report text to differentiate the caption from the report body. Notice the stylization of the caption in Figure 2. When referring to your figure, avoid phrases like "as shown on below", "as seen on the following page" because your figure may not always print as intended. It is clear to simply number the figure and refer to it by its number in the text.

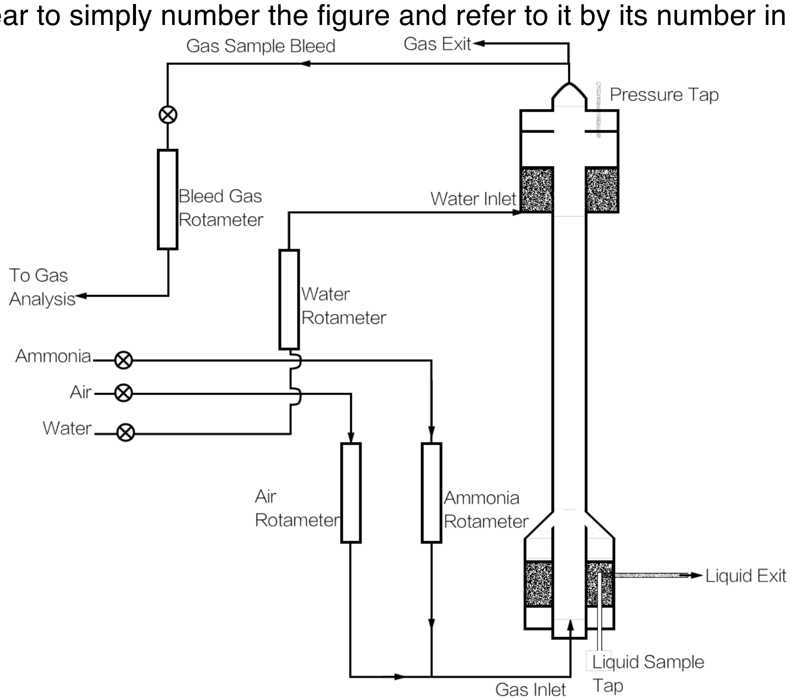

Figure 2: Schematic diagram of the experimental apparatus to measure mass transfer coefficient for ammonia absorption.

Illustrations

1. Do not copy illustrations from any source. **<u>You must make your own schematics.</u>**
    a. Software suggestions to help construct schematics: MS Visio, MS Powerpoint, MS Paint, lucidchart.com, and digikey.com/schemeit
2. Give the drawing a clear title and a figure number: center the title below the drawing.
3. Label the parts for easy reference. Use arrows if necessary.
4. Depending on the complexity of the drawing, assign numbers or letters to each part with an accompanying key or legend.
5. Include dimensions when necessary.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Formatting for Visuals</u>

Graphs and Data Presentation

Presenting your data in an accurate and concise manner is required for a quality lab report. It is up to you to figure out the best way to display the data analysis from your lab. Figures 3 and 4 are included as examples of how to present your analysis data. Figure 3 is a representation of a low quality presentation. Figure 4 displays a better way to present data. Both graphs were made in Microsoft Excel. The following list shows why Figure 3 is not the best way to present the data.

- A chart title is given at the top of the graph. This is unnecessary since your reader can clearly see that the graph shows the wall shear stress as a function of wall shear rate.
- The units are not included on the axis title.
- The differences in the data series are shown by color difference only. This will not work is your report is printed in black and white.
- The legend takes up a lot of space on the right hand side.
- The grid-lines are distracting.
- The caption leaves a lot to be desired. The figure caption should be descriptive and should allow your figure to stand-alone from the text. Your figure caption should convey the following information:
    - What does the graph show?
    - Why is it important?
    - What conclusion can be drawn from the graph?
- The inclusion of regression equations is distracting; they are small, improperly placed, and contain too many significant digits. The importance of fitting the data to an equation is not given in the descriptive caption.
- Acronym (LBG) is not defined.

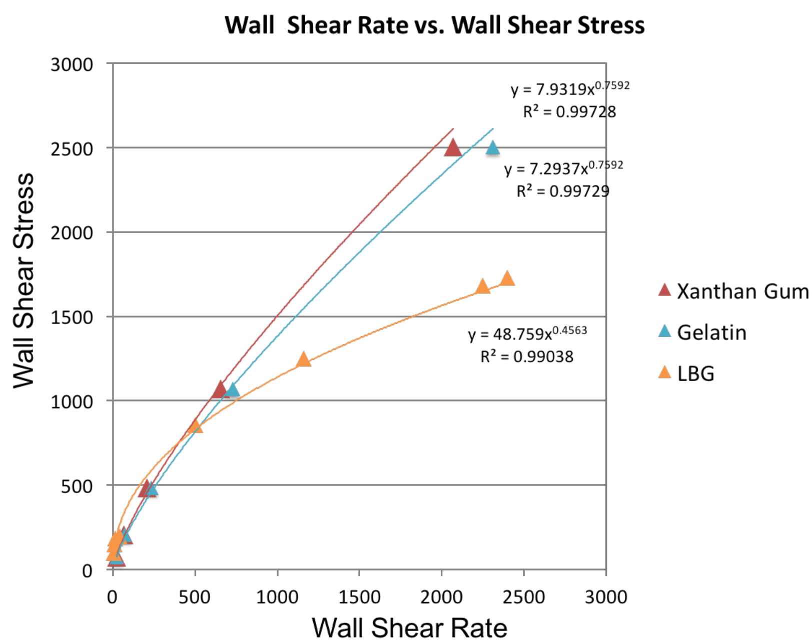

Figure 3: Wall shear rate as a function of shear stress. The red triangles show the xanthan gum, the blue shows the gelatin and the orange is the LBG. The data fit well to show shear thinning behavior and the equations show the consistency index and the flow behavior index.

<u>Formatting for Visuals</u>

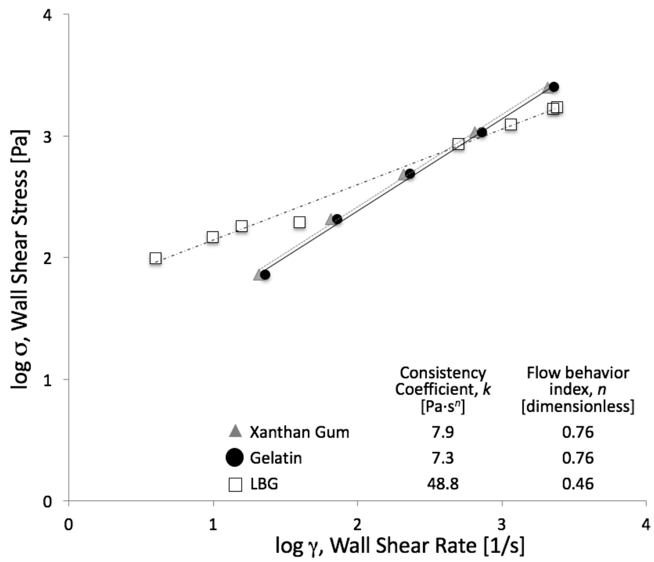

Figure 4: Behavior profile for xanthan gum(▲), gelatin (●) and locust bean gum (☐) determined using a capillary flow viscometer at room temperature (22˚C). The profile was plotted as a log-log plot to demonstrate the linear relationship between. Linear regression was performed to determine the fluid type; all regression lines had an R^2 value >0.98. The three solutions all exhibited shear thinning behavior and was verified using the value of the flow behavior index, *n*, which was <1 in each case.

Tables

- Tables of information or data

The caption for a table should be placed above the table and should line up with the left side of the table. The caption should be descriptive enough that the reader can understand the table without referring to the text. All tables should be referenced in the text before they appear in your report. An example, Table 1 is included on this page. Notice that in the sentence the first letter of the word *TABLE* is capitalized when referring to a table. The font for the table caption should be 1 point smaller than the font for the report text. Notice the stylization of the caption in Table 1. Tables should be well organized and should clearly show the independent variable.

Table 1: Experimental results for K_{og}. The flow rate, Q, was the independent variable and ranged from 70 to 150 L/min.

Q [L/min]	U [m/s]	L [L/min]	K_{og} [mol NH_3/m^2•s•atm]
70	2.42	0.80	0.78*
90	3.12	0.80	1.00
110	3.81	0.80	1.09
130	4.41	0.80	1.21
150	5.19	0.80	1.37

*A sample calculation to find this result is found in the sample calculation section of the appendix

<u>Special note:</u> Take note of the significant figures (SigFigs) in your reports. Many of you calculations will be performed and reported using Microsoft Excel, which will gladly spit out as many SigFigs as you want. However, this is not good practice; especially when reporting on experimental data. If the tool you use in the lab is only able to measure one SigFig, then you can only report one SigFig in your analysis. If the tool you use is able to report three SigFigs, then you can use three SigFigs.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Formatting for Visuals</u>

Equations

If you add an equation to your report, you must to refer to it in the text. This is much like you find in a textbook. You must number your equations. An example is shown in Equation 1. Notice that in the previous sentence the first letter of the word *EQUATION* is capitalized when referring to an equation in the text. The equation should be tabbed to start at 2" in from the left margin and the designation number should be right justified as shown in Equation 1. Do not forget to explain the terms in your equations.

$$K_{og} = \frac{W}{a \cdot z \cdot \Delta P_{LM}} \tag{1}$$

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
Citations for ALL Reports

References and Citations

Content

References are used to help your reader understand where your information is originally from and allows them to look up the reference in case they would like additional information. If you read something and then use this information to help write your report, it should be referenced at the end of the sentence. You need to put what you read into your own thoughts. Using more than a few words from a source is considered plagiarism and should be avoided at all costs. The Purdue OWL (Online Writing Lab) is an excellent resource regarding what is plagiarism and how to avoid it. The OWL can help you with citations and references.

For this course, you are expected to use authored resources for your citations. You may **not** use the pre-labs, presentations, or lab manuals as a source in your reports.

1. Only scientific journals, reference books, textbooks, official government publications (e.g. FDA, CDC, NIH, EPA, etc.) should be used as references for technical content in your reports.

2. Do NOT use websites such as eHow, Wikipedia, EngineeringToolbox as your source. There is no guarantee that information on these sites is correct. Some of it can be wrong or misleading. You would never want to reference these types of sites in any sort of professional output. As a student, wrong or misleading information can significantly undermine your learning.

Formatting

In text citations should be formatted as follows:

> Liquid-liquid extraction is employed when a component of interest in a mixture can be removed by a component using a second liquid phase (Geankoplis, 2010). A method that lends itself to a larger scale and uses water as an effective extraction solvent is pressurized liquid extraction (PLE), or sub-critical fluid extraction. PLE uses liquids at an elevated temperature, below the critical point, which enhances the extraction kinetics of the solvent and uses increased pressures to keep the solvent in liquid form (Wang and Weller, 2006). Water is a more effective solvent, for extracting organic compounds, when under pressure and at elevated temperatures because, as the temperature of water increases yet still remains below its critical point, the dielectric constant of water decreases, which leads to a decrease in the polarity of water (Ong *et al.*, 2006). Organic compounds are more soluble in less polar solvents, thus making sub-critical pressurized water a better extraction solvent for many natural products (Shotipruk *et al.*, 2004).

The resulting references in the literature cited would be formatted as shown below.

Geankoplis, C. (2010). *Transport Processes and Separation Process Principles*. Upper Saddle River, NJ: Prentice Hall, pg 776.
Ong, E. S., J. S. H. Cheong and D. Goh (2006). Pressurized hot water extraction of bioactive or marker compounds in botanicals and medicinal plant materials. Journal of Chromatography A, 1112(1-2): 92-102.
Shotipruk, A., J. Kiatsongserm, P. Pavasant, M. Goto and M. Sasaki (2004). Pressurized hot water extraction of anthraquinones from the roots of *Morinda citrifolia*. Biotechnology Progress, 20(6): 1872-1875.
Wang, L. J. and C. L. Weller (2006). Recent advances in extraction of nutraceuticals from plants. Trends in Food Science & Technology, 17(6): 300-312.

Report Guidelines
ABE 304: Bioprocess Engineering Laboratory
<u>Sample Calculations</u>

How to Include Sample Calculations

Sample calculations need to be included to demonstrate how a value was determined for your data analysis. Sample calculations need to be hand-written on Engineering Problems Paper and added as an appendix to your report. The sample calculations should be completed in a methodical manner and should be easy to follow. An example of the calculations is shown in the following pages.

An outline of the calculations used to obtain final results from the experimental data

Annotations shown in red

SAMPLE CALCULATIONS

ALL for $Q_{AIR} = 70\ L/min$

Identify the basis for calculation

NH_3 Concentration of Liquid Stream, exit

$$2NH_3(aq) + H_2SO_4(aq) = 2NH_4^+ + SO_4^-$$

8.5 mL of 0.1 M H_2SO_4 was used to titrate a 25 mL sample.

$$C_{NH_3} = \left(\frac{8.5\text{ mL } H_2SO_4}{25\text{ mL sample}}\right)\left(\frac{0.1\text{ M } H_2SO_4}{L}\right)\left(\frac{2\text{ mol } NH_3}{\text{mol } H_2SO_4}\right)$$

$$\boxed{C_{NH_3} = 0.068\ \frac{\text{mol } NH_3}{L}}$$

Identify what is being calculated

Partial Pressure (P^*) @ Equilibrium w/ EXIT LIQUID

@ 20°C, the Henry's Law Constant $H = 7.37\times10^{-3}\text{ ATM}\left(\frac{100\text{ g } H_2O}{\text{g } NH_3}\right)$

State necessary constants and assumptions

$$P_{NH_3} = HC_{NH_3}$$

$$P^* = 7.37\times10^{-3}\text{ ATM}\left(\frac{100\text{ g } H_2O}{\text{g } NH_3}\right)\left(\frac{0.068\text{ mol } NH_3}{\text{L. Solution}}\right)\left(\frac{17\text{ g } NH_3}{\text{mol } NH_3}\right)\left(\frac{1\text{ L}}{1000\text{ g } H_2O}\right)$$

Show all units

$$\boxed{P^* = 8.55\times10^{-4}\text{ ATM}}$$

→ the density of the solution ≈ density of H_2O

$\Delta P_2 = P_{g2} - P^*_2$, driving force @ bottom of column

$$P_{g2} = (2/102) * 1\text{ ATM} = 0.0196\text{ ATM}$$

$$\boxed{\Delta P_2 = 0.0196\text{ ATM} - 8.55\times10^{-4} = 0.0188\text{ ATM}}$$

NH_3 Partial pressure in exit gas

Volume of Bleed gas titrated $= \frac{0.380\text{ L}}{\text{min}} \cdot \frac{1\text{ min}}{60\text{ s}} \cdot 292\text{ s} = 1.85\text{ L}$

moles of Bleed gas ⇒ $n = \frac{PV}{RT} = \frac{1\text{ ATM} * 1.85\text{ L}}{0.0821\frac{\text{L}\cdot\text{ATM}}{\text{mol}\cdot\text{K}}(293\text{K})} = 7.70\times10^{-2}\text{ mol}$

n_{NH_3} = moles of NH_3 in Bleed gas sample $= \left(\frac{0.01\text{ M } H_2SO_4}{L}\right)(0.01\text{ L})\left(\frac{2\text{ mol } NH_3}{\text{mol } H_2SO_4}\right)$

$$= 2\times10^{-4}\text{ mol } NH_3$$

$$\boxed{P_1 = \frac{n_{NH_3}}{n_{\text{Bleed gas}}}\times 1\text{ ATM} = \frac{2\times10^{-4}}{7.70\times10^{-2}}\times 1 = 2.60\times10^{-3}\text{ ATM}}$$

$\Delta P_1 = P_{g1} - P_1^*$, driving force @ top of column

$P_{g1} = 2.60 \times 10^{-3}$; $P_1^* = 0$, since there was no NH_3 in water feed

$\boxed{\Delta P_1 = 2.60 \times 10^{-3} \text{ ATM}}$

Overall mass transfer coefficient, K_{og}

$$K_{og} = \frac{W}{a z \Delta P_{LM}}$$

W = total NH_3 transferred $= Q_{EXIT\ Liquid} \times C_{NH_3} = 0.8\ L/min \left(\frac{1\ min}{60 s}\right)\left(\frac{0.068\ mol}{L}\right)$

$W = 9.07 \times 10^{-4}$ mol/s

$az = \pi d z = 3.14\,(0.0254\ m)(1.79\ m) = 0.143\ m^2$

$$\Delta P_{LM} = \frac{\Delta P_1 - \Delta P_2}{\ln \Delta P_1 / \Delta P_2} = \frac{2.60 \times 10^{-3} - 0.0188}{\ln\left(2.60 \times 10^{-3} / 0.0188\right)} = 8.19 \times 10^{-3} \text{ ATM}$$

$$\boxed{K_{og} = \frac{9.07 \times 10^{-4}\ mol/s}{0.143\ m^2 \cdot 8.19 \times 10^{-3}\ ATM} = 0.775 \frac{mol\ NH_3}{m^2 \cdot s \cdot atm}}$$

U = Average gas velocity

$$U = (71.4\ L/min)\left(\frac{min}{60 s}\right)\left(\frac{4}{\pi (0.0254 m)^2}\right)\left(1\ m^3 / 1000 L\right)$$

$U = 2.42$ m/s

Calculation of k_g and k_L

$$1/K_{og} = 1/k_g + H/k_L = 1/BU^{0.83} + H/k_L$$

Linear regression was used to fit the Plot of $1/K_{og}$ vs. $1/U^{0.83}$ (See Figure 2)

The slope = $1/B = 2.36$; the intercept $= H/k_L = 0.096 \frac{m^2 s\, atm}{mol\ NH_3}$

For $Q_{air} = 70$ L/min

$$\boxed{k_g = BU^{0.83} = \left(\frac{1}{2.36}\right)(2.42)^{0.83} = 0.86\ mol\ NH_3 / m^2 \cdot s \cdot atm}$$

$$k_L = H/\text{intercept} = 7.37 \times 10^{-3}\ atm \left(\frac{105\ g\ H_2O}{g\ NH_3}\right)\left(\frac{17 g\ NH_3}{mol\ NH_3}\right)\left(\frac{L}{1000 g\ H_2O}\right) \cdot \frac{mol\ NH_3}{0.096\ m^2 \cdot s \cdot atm}$$

$$\boxed{k_L = 1.31 \times 10^{-4}\ m/s}$$

CALCULATION of k_g using Sherwood-Gilliland Correlation

$$SH = 0.023\ Re^{0.83}\ Sc^{0.44}$$

$$Sc = \mu / \rho_{air} D_{NH_3-AIR} = \frac{1.7 \times 10^{-5}}{1.30\ (2.2 \times 10^{-5})} = 0.595$$

$@\ 0°C,\ D_{NH_3-AIR} = 1.98 \times 10^{-5}\ m^2/s$ (TREYBAL, R.E., *Mass Transfer Operations*, 3rd Ed. McGraw-Hill, 1980)

$D \propto T^{3/2}$ so @ $20°C$, $D_{NH_3-AIR} = \left(\frac{293}{273}\right)^{3/2} \times 1.98 \times 10^{-5}$

$$= \underline{2.20 \times 10^{-5}\ m^2/s}$$

$\mu_{air} = 0.017\ C_p = 1.7 \times 10^{-5}\ Pa\ s.$

$\rho = 1.30\ kg/m^3$

$$Re = \frac{d u \rho}{\mu} = \frac{(0.0254 m)(2.42\ m/s)(1.30\ kg/m^3)}{1.7 \times 10^{-5}\ Pa \cdot s} = 4630$$

$$SH = 0.023 (4630)^{0.83} (0.595)^{0.44} = 20.3 = \frac{k_g R T d}{D_{NH_3-AIR}}$$

$$k_g = \frac{SH \cdot D_{NH_3-air}}{RTd} = \frac{20.3\ (2.2 \times 10^{-5}\ m^2/s)(1.013 \times 10^5\ Pa/atm)}{(8.314 \frac{m^3\ Pa}{mol \cdot K})(293\ k)\ (0.0254 m)}$$

$$\boxed{k_g = 0.073 \frac{mol\ NH_3}{m^2 \cdot s \cdot atm}}$$

Clearly box final answers or significant calculations

Laboratory Notebooks
ABE 304: Bioprocess Engineering Laboratory
Guidelines and Grading Rubric

Laboratory Notebook Guidelines and Grading Rubric

Rationale. Whether in industry, academic, or government work environments, laboratory notebooks are critical documents for research and engineering design. They are *primary legal documentation of inventions* and can be the basis for supporting intellectual property and patent applications. They are also the documentation that allows anyone (including you at a later date) to repeat and perform the same procedures in the future. Science and engineering is founded in this principle called *autonomous replication*. Our entire framework of science and engineering is based on only accepted scientific results that can be reliably replicated by others.
Features of a Good Lab Notebook

- ☐ Contains enough detail that another person of comparable skill could repeat your experiment and obtain the same results using only the lab notebook.
    - Contains complete protocols
    - Contains thorough observations
    - Contains all raw data and calculations

- ☐ Contains enough detail that you can effectively troubleshoot your procedures should you obtain results that are not what you expect.

- ☐ Is neat and easy to read by you and others
- ☐ Makes use of tables, figures, photographs and drawings to organize data and illustrate procedures, set-up, observations, and results
- ☐ Each page contains a date and your signature at the bottom
- ☐ Uses headers to organize all required sections
    - Aim/purpose
    - Materials & Equipment Set-Up
        - Includes process diagram or drawing of equipment set-up
    - Procedures and Protocols
        - Includes all variables and order that they were varied
        - Should be detailed and step-by-step accounting of what you did
    - Results
        - All raw data
        - Organize numbers into tables when appropriate
        - Make and document observations
        - Sketch/Graph data as you go.
        - Tape in all photographs, images, printouts, etc. Date and initial each taped in item
    - Calculations that were made for the procedures
        - E.g. dilution calculations, mass to mole conversions for weigh outs etc.
- ☐ Analysis and Interpretation
    - Document your thoughts and observations on the results
    - Rationale and your thought process of why you did what you did
    - What you think the data means at the time you are recording it
    - Preliminary conclusions from the experiment

Laboratory Notebooks
ABE 304: Bioprocess Engineering Laboratory
Guidelines and Grading Rubric

Lab Notebook Rubric

A Level Work

Contains all Features of a Good Lab Notebook. Contains signatures, extremely neat, complete protocols, thorough observations, contains all data and calculations, contains all images and drawings, someone could repeat work from documentation.

B Level Work

Written with needed headers, may be missing some detail, but contains most of the data, however, someone might have difficulty repeating the experiment

C Level Work

Log style only (no headers e.g. objectives, rationale, results, next steps), may contain data but overall insufficient to repeat the experiment

D Level Work

Extremely brief, missing most major components
Clear that content was recorded well after the actual experiment
Impossible to repeat experiment

F Level Work

Entire lab sections or entire lab notebook missing