Title of Lab

Student Name

Class and section number

Instructor

Date lab performed

INTRODUCTION

[Double space. Write in 3rd person past tense. Write in paragraphs, not in bulleted lists. Think about your reason for doing the lab. What were you investigating? What was your focus? Is there any important background information that someone should know prior to reading your lab report? Be sure to include citations if you are using sources for any background information. Are there any important equations that you'll be using? What did you think was going to happen? Why did you think you'd get the results you predicted?]

First sentence: The purpose of the lab was to…

Last sentence: The hypothesis was that…

MATERIALS

[Make a bulleted list. Do not include safety equipment.]

PROCEDURE

[Double space. Write in 3rd person past tense. Write in paragraphs, not in a bulleted or numbered list. Describe exactly how you performed the experiment. Do not describe the steps like they are a recipe—you have already done this experiment. You are not writing instructions. What were the exact steps you did in the exact order you did them? Provide just enough detail so that someone of your level or higher could perform the lab precisely how you did.]

DATA/RESULTS

[Double space. Write in 3rd person past tense. Write in paragraphs, not in a bulleted list. This section includes observations (measurable information that your perceived through your senses) and raw data. Organize and present your data using charts and tables. Do not perform any math on your results. Remember that tables have titles and figures have captions. Be sure that the correct unit abbreviations are in your tables' headers, not in the data cells. Remember to label both the x-axis and y-axis of charts and keep their design as basic as possible. Number tables and figures consecutively for the whole lab. Keep their designs similar.]

Sample table:

Table 1: The title of the table in sentence case.				
Unknown	Mass (kg)	Volume (l)	Velocity (km/hr)	Time (s)
Unknown 1				
Unknown 2				
Unknown 3				
Unknown 4				

DATA PRESENTATION/ANALYSIS

[Double space. Write in 3rd person past tense. Write in paragraphs, not in a bulleted list. Provide any equations that you applied to the data. Give the general equation and a specific example from your data. Organize and present your data using charts and tables. Remember that tables have titles and figures have captions. Be sure that the correct unit abbreviations are in your tables' headers, not in the data cells. Remember to label both the x-axis and y-axis of charts and keep their design as basic as possible. Number tables and figures consecutively for the whole lab. Keep their designs similar.

Describe any errors you encountered—think about accidents that happened (human error), limitations with the equipment or supplies, and problems with the experimental design. Here you should also discuss instances in which you and your partner(s) had conflicting data. What were the sources of these errors? What was the relative impact of each?]

Sample graph:

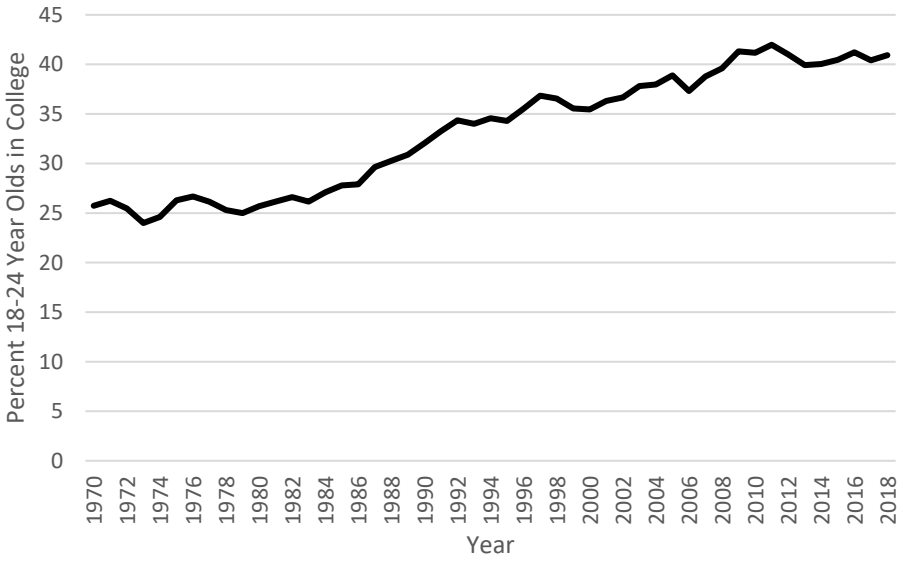

Fig. 1. Percent of 18-24 year olds in college in the US, 1970-2018.

CONCLUSION

[Double space. Write in 3rd person past tense. Write in paragraphs, not in a bulleted list. Your conclusion must be clearly and logically drawn from the data provided, with a logical chain of reasoning from hypothesis to data to conclusions clearly and persuasively explained. Conflicting data, if present, must be explained.]

APPENDICES

[Include photos of any notes or measurements you took during the lab.]

LAB REPORTS:

The purpose of a lab report

- Writing a formal lab report is an important skill.
- As STEM students progress through their degrees, labs will become more complex and challenging.
- Lab reports will gradually become more and more formal.
- It is important to understand how a lab report is structured as early as possible as these skills take a while to develop.

The purpose of a lab report

- A lab report details experimental procedures and findings that have already occurred.
- Written with enough detail:
  - so that someone can replicate your experiment;
  - so that no one has to replicate your experiment; and
  - so that every step in your work can be analyzed.

The audience of a lab report

- The audience for a lab report changes with your level of education and as you rise through your career.
- For these early experiments, imagine that someone in your class missed a lab.
- Write with enough detail so that they can understand what they missed and recreate what happened in their imagination.

The audience of a lab report

- Eventually, the people who read your lab reports might include:
  - STEM professionals who are skeptical of your findings and want to recreate the lab themselves;
  - Grant-giving foundations, government officials, regulatory agencies, lobbyists, or special interest groups; and
  - News organizations or even hostile third parties who obtain your work through a Freedom of Information Act request.

The audience of a lab report

- Freedom of Information Act requests apply to anyone who receives government support for a research project, no matter how small the sum of money.
- If you are being supervised by a professor and are performing part of an experiment for which she has received government grant money, the public has a right to see your research.
- Your university will fight to keep your work confidential, but they will always lose, and you will have to produce your work.
- Be sure that you are always honest.

Pre-writing

- No one has ever received a lower grade for writing a longer, more complete and more competent lab report.
- A lab report might only account for a small portion of your grade, but you should always do your best.
- That small part of your grade might be the difference between a B and an A.
- As you move through STEM, your ability to document your ideas and experiments will become more and more important.

Pre-writing

- Create a flowchart for the combined lab and the report.
- Create a checklist of necessary tasks.
- Create an outline for the lab report.
  - The more detailed the outline, the better the resulting report
  - At each stage of the outline, make a note of things that could go wrong or if the stage seems in any way inadequately designed (this is for the Discussion section)

Pre-writing

- Do NOT write a lab report in sequential order:
  - Write the Introduction before the lab to ensure that you understand the Objective, the necessary background, the underlying theories, and your hypothesis.
  - Write the Procedure immediately after the lab, while what you did is still fresh in your memory.
  - Take your time and write the Results, Analysis and Discussion when you are ready.
  - Finally, clean everything up and if required, write your Conclusion, list your References, and create an Abstract and Keywords. Remember to put your lab notes at the end in an Appendix. You always have to save your lab notes.

Writing style

- Write in past tense—your lab has already happened.
- Keep sentences under 15 words.
- Do not use contractions.
- Do not use personal pronouns.
- Do not address the reader.
- Do not ask rhetorical questions.
- Use appropriate technical language.
- Use SI and SI-derived units only.

About pronouns

- Pronouns can lead to confusion, so limit the use of pronouns.
- For example, instead of writing: “The reaction was exothermic. It took five minutes.”
- You should write: “The reaction was exothermic. The reaction took five minutes.”
- Your goal is to write simply and clearly so that non-native speakers of English in your discipline can understand precisely what you mean.

Advice on collaboration

- Do not automatically trust your lab partners.
- You do not know who the good students are.
- You do not know who is going to drop out mid-semester.
- Once you are in the workplace, you may be held accountable for problems other people caused.
- Learn how to deal with problems now, before your job is on the line.
- Be quick to report problems in collaborative projects.
- In the real world, you may even be held legally responsible for mistakes in the lab.
- Do not have emotions about this issue.

Advice on collaboration

- In a collaborative project:
  - Keep track of each team member's responsibilities;
  - Use a check list or learn how to make a Gantt Chart;
  - Check in on team members regularly via text, Discord or some other app;
  - Maintain one master copy of a team document;
  - Learn how to use Google Docs and Dropbox; and
  - Keep secondary copies of important documents on a flash drive and in your student email and in your gmail.

Advice on collaboration

- Learn to critique one another's work
  - Do not have an ego;
  - Science is more important than your feelings;
  - That said, it is best to wait a few hours between writing and proofreading your lab report to give yourself some emotional distance;
  - To avoid accusations of plagiarism, do not do more than minor editing of someone else's lab report; and
  - Remember that submitting duplicate lab reports is plagiarism.

Lab report organization

- Although there are a few different models, the typical formal lab report is organized into the following sections:

Title page
Abstract and Keywords
Introduction
Objectives
Materials
Procedure
Results
Analysis
Discussion
Conclusion
References
Appendices

Title Page

Lab Reports

Title Page

- Unless you are directed to write your own lab report title, just use the one provided with the lab manual or other instructional materials.
- Center your lab report title at the top of the page.
- Go down a few lines and center your full name as it appears on your CUNY registration.
- Then go down to the bottom of the page and center:
  - The abbreviation and number of your class with its section ID;
  - Your professor’s name; and
  - The date that the lab was performed.

Title Page

Lab 4: Determination of pH

Carl James Grindley

CHEM 200: 001

Professor Neslon Nuñez-Rodríguez

Sept. 20, 2020

Abstract and Keywords

Lab Reports

Abstract

- Seldom required in freshman or sophomore courses.
- Should be very simple:
  - One paragraph;
  - 5-10 sentences;
  - 1-2 sentences for each section of the lab report; and
  - 75-200 words.
- Two basic types:
  - Descriptive—just states topic and describes experiment; and
  - Informative—also includes the results and conclusions.

Abstract

- Abstracts will contain the following “sections” of one to two sentences each:
  - Introduction
  - Procedures
  - Results
  - Discussion
  - Conclusions

Abstract

- An abstract:
  - Does not ask questions;
  - Does not refer to specific sections of the report;
  - Does not cite figures;
  - Does not cite scholarship unless the lab is in direct response to someone else’s published lab;

Keywords

- Keywords are also called Subject Terms.
- They range from single words to short terms.
- They are the way that librarians categorize articles and books.
- Imagine a search for an article as a Venn Diagram…
- If I search for articles using five keywords—Exxon Valdez; Prince William Sound, Alaska; Oil Spills; Shipping Accidents; Wildlife—I should find articles about how the Exxon Valdez oil spill affected wildlife.

Keywords

- So if you are asked to come up with some Keywords for your labs, try to think of ways that you can reduce the lab down to searchable elements that when combined would result in someone finding your work out of thousands of other reports.
- It is a very difficult skill to learn.

Introduction

Lab Reports

Introduction

- 1 paragraph to 2 pages.
- Write it before you do the lab in order to make sure that you fully understand the theories you are using and the experimental design and hypothesis that you are testing.
- Use third person passive past tense.

Introduction

- The Purpose and the Hypothesis are required parts of a lab report Introduction.
- In an Introduction:
  - Your very first sentence will probably be your Purpose.
  - Your very last sentence will probably be your Hypothesis.

Introduction

- Purpose: What specific result are you trying to achieve during the lab? What is your aim? Your goal?
- The easiest way to write a purpose is to start with a stock phrase:

The purpose of the lab was…

- Then use the infinitive verb that best describes what you were trying to do:

To determine…

To distinguish…

To measure…

To describe…

To separate…

To identify…

To calculate…

To catalog…

Introduction

- Then just finish the sentence by thinking about the overall subject that the lab concerns.

The purpose of the lab was to explore concepts in stoichiometry.

Introduction

Example purpose statements:

The purpose of the experiment was to determine the percentage by mass of acetic acid in vinegar using acid/base titration.

The purpose of this investigation was to determine the effects of environmentally realistic exposures of acid precipitation on productivity of field-grown and chamber-grown peanuts.

Introduction

- Your second sentence in your Introduction will usually be your Hypothesis.
- A Hypothesis is an inherently testable claim that takes a concrete position, and usually predicts a relationship between at least one independent variable and one dependent variable.
- Sometimes a Hypothesis is followed by a Null Hypothesis that claims that there is no relationship between variables.
- In more complex experiments, both the Hypothesis and Null Hypothesis will be tested and mathematically analyzed.

Introduction

- Write your hypothesis in past tense because it is the theory that the lab was designed to test.
- Make it obvious—in a very simple way—how the experiment was conducted.
- Don’t sit on the fence. Make an actual claim. Suggest a relationship between variables.
- Leave yourself out of it. Never use personal pronouns in STEM. Your lab worked because the science worked. It did not work because you were in the lab. As long as the procedures are carried out correctly, it does not matter who filled the test tubes.

Introduction

The hypothesis was that environmentally realistic exposures of acid precipitation would negatively affect the germination of lima beans (P. lunatus).

The null hypothesis was that environmentally realistic exposures of acid precipitation would not affect the productivity of lima beans (P. lunatus).

Introduction

- Which hypothesis is better:

I hypothesize that there is a significant relationship between the temperature of a solvent and the rate at which a solute dissolves.

It was hypothesized that as the temperature of a solvent increases, the rate at which a solute will dissolve in that solvent increases.

Introduction

- Purpose
- Definition(s)
- Importance
- Background
- Equation(s)
- Explain units
- Walkthrough of equation(s)
- Examples
- Experimental design
- Hypothesis
- Null hypothesis

You may pick and choose from these items as necessary, but always include Purpose and Hypothesis as your first and last items

Introduction

Basic

Purpose

Hypothesis

Intermediate

Purpose

Background

Hypothesis

Advanced

Purpose

Background

Equations

Experimental design

Hypothesis

Null Hypothesis

Introduction

- In beginning STEM courses, common sources for your introduction include the class text book, the lab manual, and your lecture notes.
- Do not get into the habit of using Wikipedia—some instructors will fail you for using it.
- Refereed articles are always better than other sources.
- Make sure you document your sources.
- Some instructors will want CSE, some will want IEEE, some might even want APA. Since there are significant differences between these styles, always check the assignment prompt, or ask your instructor

Objectives

Lab Reports

Objectives

- Not all lab reports will contain an Objectives section.
- Some instructors will want a list or paragraph of specific Objectives either in the Introduction or between the Introduction and the Materials.
- Usually, the Objectives will be found in the Lab Manual.
- Objectives are usually concrete and verifiable.

Objectives

- Remember to write in third person, passive past tense.
- The objectives of this lab were to safely use a Bunsen burner to dry a compound, to use vernier calipers to make measurements, to correctly measure a liquid in a graduated cylinder, and to safely handle hazardous chemicals in a lab setting.

Materials

Lab Reports

Materials

- Ensure that the Materials list is complete and accurate.
- Usually a bulleted list.
- Exclude safety equipment such as your safety glasses, nitrile gloves, closed-toe shoes etc.
- Sometimes you might want to photograph your experimental set up so that you can accurately describe components later.
- Do not rely on the lab manual as your lab equipment might not be the same as in the manual.
- Be specific and include manufacturers and model numbers.

Materials

- Distinguish between water and distilled water.
- Keep track of makes and model numbers—some digital balances for example, will have different levels of accuracy or precision that can affect experimental error.
- Even something as simple as a graduated cylinder can contribute to experimental error.

Materials

- For example, Class B glassware has twice the specified range as Class A glassware.
- If a Class A flask has an accuracy of +/- .5 mL, then a Class B flask will have an accuracy of +/- 1 mL.
- Class A glassware is usually made of borosilicate glass and is therefore resistant to chemicals and temperature extremes, whereas Class B glassware can be made of soda-lime glass and might not be ideal for long exposures to chemicals or changes in temperature.

Procedure

Lab Reports

Procedure

- Sometimes also called Methods.
- The most difficult part of the lab report.
- Records a shortened and slightly idealized version of what actually happened when the lab was performed.
- Traditionally uses a very challenging writing style.

Procedure

- Written in:
  - The third person because you are not an important part of the experiment.
  - The passive voice to provide emotional distance.
  - The past tense because the lab has already occurred.

Procedure

- Some professors will let you photocopy lab procedures from a handout or the lab manual.
- You should instead ask for permission to practice writing formal lab Procedures in order to prepare for more advanced coursework.
- In a just world, one will ever penalize you for doing a more complete job.

Procedure

- Omit:
  - Results—instead refer the reader to the appropriate data table;
  - Discussion—don’t even mention what happened or why it happened; and
  - Math—don’t perform any calculations no matter how simple.
- Merely state exactly what you did in the specific order that you did it.
- Your goal is for other STEM professionals to be able to recreate your experiment based on your Procedure.

Procedure

- Omit:
  - Procedures specific to the lab in which you are working;
  - Basic procedures that appear in earlier labs (e.g. how to correctly read a graduated cylinder);
  - How you set up your equipment;
  - Basic health and safety instructions;
  - Clean up; and
  - Errors, mistakes and disasters.
- It is safe to assume that the person reading your Procedure knows to wear close-toed shoes and to dispose of hazardous chemicals safely and legally.

Procedure

- Leave out minor mistakes such as a spillage, breaking a glass rod, holding the thermometer incorrectly, and so on.
- These will be documented and their potential effects discussed in the Discussion section.

Procedure

Unknown #1 was poured into a 150 mL graduated cylinder and the volume recorded (Table 1). Unknown #3 was poured into a 150 mL graduated cylinder and the volume recorded (Table 1). Unknown #1 was poured into 250 mL Erlenmeyer flask, and Unknown #2 was added. The resulting solution was stirred with a glass rod for 30 s, then the temperature of the solution was recorded (Table 1).

Results

Lab Reports

Results

- Results and Analysis are sometimes conflated into a single section.
- Results typically mean experimental data.
- Results do not contain any math.
- Present results in the form of text, data tables, and figures.
- Present your results in the order that you obtained them.
- Be sure that any tables or figures referenced in your Procedure appear in the order and numbering you specified.

Results

- There are design guidelines for data tables, and for all types of figures.
- All figures and tables must be referenced in the text before you show them (usually referenced first in the Procedure).
- You should not include a table or a figure without introducing it.

Results

- The most common way to present your results is through a data table.
- The table should follow this basic design.

Table 1: Measurements			
Unknown	Mass (g)	Temp. (c)	Volume (mL)
Unknown 1			
Unknown 2			
Unknown 3			

Results

Table 1: Measurements			
Unknown	Mass (g)	Temp. (c)	Volume (mL)
Unknown 1	23.334	2.02	18
Unknown 2	18.633	9.06	46
Unknown 3	22.917	10.42	22

- Make sure the table's title is the same that you referenced in the Procedure.
- Make sure all the cells have clear borders.
- Do not use bold face or italics.
- Put unit abbreviations in the header of each column, not in the cells.
- Do not include any mathematical operations.
- Preserve significant figures.

Analysis

Lab Reports

Analysis

- Analysis presents calculations based on the equations described in the Introduction and the data from Results.
- Analysis also summarizes Results and its own calculations using figures.

Analysis

The density of each unknown was calculated using Eq. 1.

$$\text{Density} = \frac{(\text{mass } 1\text{-}4)/4}{(\text{volume } 2 - \text{volume } 1)}$$

For unknown 1:

$$12\ \text{g/mL} = \frac{(480\ \text{g}) / 4}{(40\ \text{mL} - 30\ \text{mL})}$$

The same calculation was used to determine the densities of unknowns 2-7 (Table 2).

Table 2: Calculation of Density

Unknown	Mass 1 (g)	Mass 2 (g)	Mass 3 (g)	Mass 4 (g)	Total Mass (g)	Average Mass (g)	Initial Volume (mL)	Final Volume (mL)	Volume of Unknown (mL)	Density (g/mL)
Unknown 1	120	120	120	120	480	120	40	30	10	12
Unknown 2	120	120	120	120	480	120	40	30	10	12
Unknown 3	120	120	120	120	480	120	40	30	10	12

- If you have a series of calculations, perform the first in order to show your work, then present the rest of the calculations in a table.
- Be sure to number your table appropriately.

Analysis

Student use of campus housing is traditionally seen as an indication of engagement. The registrar's office was able to provide an analysis of student use of campus housing (Fig. 1).

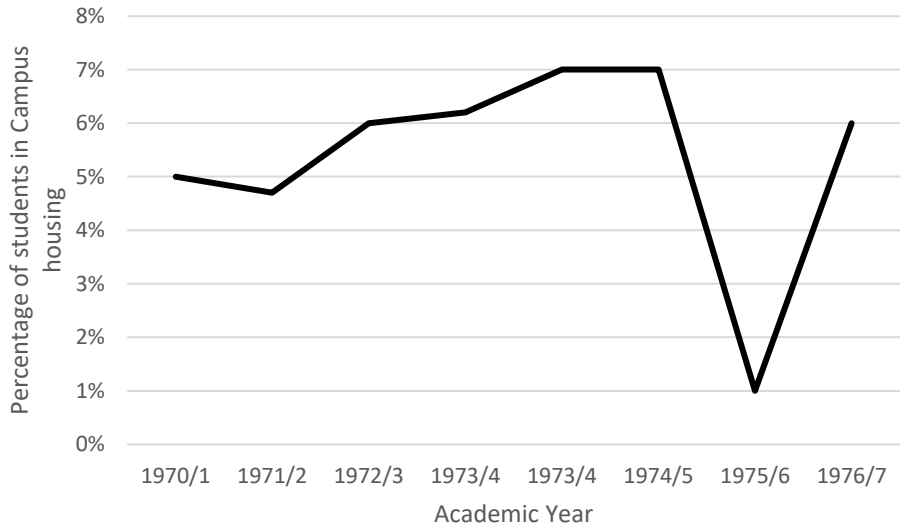

Fig. 1. Percentage of enrolled students in campus housing in Miskatonic University, academic year 1970/71 to 1976/7.

- Introduce a figure—even very simply—before you show the figure.
- Refer to the figure by a number.
- Figures do not have titles, they have captions.
- Label your x-axis and your y-axis
- Unless you have a complex dataset, only use black and white.
- Minimize unnecessary chart elements.
- Write clear and precise figure captions.
- Ensure that all figures are similarly numbered, designed and labeled.
- Learn how to use Excel.

Analysis

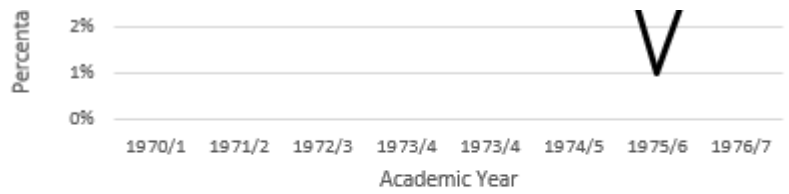

Fig. 1. Percentage of enrolled students in campus housing in Miskatonic University, academic year 1970/71 to 1976/7.

Fig. 1 shows the increase in student dorm room use in the early 1970s. The x-axis is the academic year and the y-axis is the percent of enrolled students who lived at any of the college's three dorms. Fig. 1 does not separate out individual use of the three dorms. The trend was that of a slow increase in dorm use during the 1970s. There was an abrupt drop in dorm use in 1975/6 due to the unexplained events that led to opening of a portal to an alternate universe. Dorm use quickly recovered next academic year.

- After you show a figure, you should discuss it for a few sentences.
- You may want to:
  - Summarize the overall meaning of the figure.
  - Describe the two axes.
  - Describe any limitations in the data.
  - Explain any trend in the data.
  - Discuss any anomalies in the data.

Discussion

Lab Reports

Discussion

- This is the section where you discuss your purpose and hypothesis, your experimental design, your procedure, your results, and your analysis.
- A basic Discussion section will state whether or not the hypothesis was supported (never say proven) and discuss what errors may have been made.
- Traditionally, instructors will consider the Discussion the most important part of a lab report.
- A Discussion can contain many different components.

Discussion

- Addresses the hypothesis:
  - The data supports hypothesis;
  - The data does not support the hypothesis;
  - There is qualified support for the hypothesis;
  - Not enough data was gathered to support the hypothesis; and
  - The data supported the null hypothesis.
- Provides concrete references to findings.
- Explain how and why the data supports the underlying science.

Discussion

- Addresses potential error:
  - Was the equipment adequate?
  - Was the equipment used correctly?
  - Was the experimental design valid?
  - Was the experiment repeated enough times?

Discussion

- Addresses conflicting data.
- Proposes an alternate explanation for results.
- Considers broader implications of experiment.
- Suggests improvements to the experiment.
- Suggests future directions for research.

Conclusion

Lab Reports

Conclusion

- Not a reflective statement. Do not drop into first person and discuss how titrating a solution made you feel.
- It can be a single necessary sentence.
- Sometimes an instructor will want the conclusion to specifically address the Objectives (if an Objectives section was required).
- A good conclusion will always compare the actual results with the prediction.

References

Lab Reports

Works Cited

- Not a bibliography
  - Bibliographies contain all the works you read to inform you opinion of a subject, even if you did not quote them directly or paraphrase or summarize their contents
- Also called Literature Cited, References Cited, References or Reference List
  - Apply the appropriate local style
  - Easy place to lose points in a competitive environment
- Edit as an ongoing concern
- Ask a friend to attempt to find your references in whatever database you used… if he or she cannot…

Appendices

Lab Reports

Appendices

- Where you put information that does not deserve to be in the main body of the report
  - Extra information for readers looking for more details
  - Drawings of apparatus
  - Sources of hard-to-find materials
  - Calculations that elaborate on those in the Methods
  - Raw data, drawings, photographs
  - Photocopies from lab journal

Appendices

- If you wrote on a piece of paper before or during the lab, you have to include that piece of paper in your appendices. No matter how trivial. In each step—the labeling of an unknown, the way you wrote down initial measurements, the way you mapped out your process—mistakes could have occurred.