Laboratory Notebook

# Purpose:

The purpose of keeping a laboratory notebook is to keep an accurate record of all laboratory activities. Whether you are working for yourself or for a company these records are important because they may be used in court to (a) prove rights to patents or (b) defend or prosecute individuals/companies where evidence is presented that was gained through laboratory work. In the case of companies engaged in research, these records (a) may be critical to making management decisions involving millions of dollars or (b) in case of your death or departure for other reasons, are the means for your replacement to pick up the research where you left off. In all cases, the notebook belongs to the agency funding the laboratory work and is kept under their lock and key.

# Skills:

Learning to keep a laboratory notebook will help you to practice skills that are essential to your success in this course, subsequent chemistry courses, and your professional life:

* Understanding the objective, experimental procedures including safety and waste treatment, organizing your data (i.e. tables, running log)
* Keeping an accurate record of experimental procedures
	+ Learning to write data and observations directly onto your lab pages instead of loose pieces of paper
	+ Learning that it is okay to make mistakes in your lab notebook. You may want to look at your deletions at some later date, this way, your original entries will be readable**. Never use white-out or try to black-out your writing mistakes!**
		- If you record data incorrectly just draw a line through the data and initial it. Continue recording on the same page, ignoring data that has been lined out.
		- To delete paragraphs, place a single X over the entire paragraph and initial the deletion.
* Observing and collecting qualitative and quantitative data
	+ Record all data in blue or black **ink** in a legible, organized fashion.
	+ Include all relevant information. For example, in recording numbers you should include both the units and the meaning of the numbers.
* Critical thinking and experimental interpretation

# Knowledge:

Keeping a laboratory notebook will teach you to organize experimental procedures, data, and observations in an understandable way for you, your classmates, and your future colleagues. Knowing how to keep a complete, honest, readable, dated record is an essential skill in all professions including, but not limited to, scientists, engineers, medical professionals, attorneys, and many others.

# Tasks:

Before lab you will complete your prelab assignment. During lab you will collect, organize qualitative and quantitative data. After lab you will analyze and evaluate your experimental data so that it can be compiled into a laboratory report.

Before you leave lab, you must have the Data and Observation section in your notebook initialed.

## Initial set up of your lab notebook

1. Exterior Cover

Your name, course title, section and semester should go on the cover. Many other students may have the same lab notebook as you and it is important to be able to easily find yours. In the work arena, this would commonly be a project name or code and might be placed on the spine for quick identification on the shelf.

1. Title Page

Name, course title, number and section number, the name of the school, the semester and the name of your lab instructor. Also include either your address, phone or email address (in case your notebook is misplaced).

1. Table of Contents

One page should be set aside to list experiment number, experiment title, and page number(s). This is useful for quickly finding specific topics in the notebook and must be kept up to date. If your book does not come with a table of contents page be sure to leave two pages in the front to create a table of contents. Your notebook should be numbered in the upper right-hand corner.

## Using your notebook for lab

Keeping a good lab notebook will help you when you write up your lab report. Carefully read the experiment, more than once, and create a mental list of the type(s) of information you will be collecting. Plan in advance; if you need a data table, decide on the number of columns in the table and column titles and consider how much room on a page you need for your table(s) (or charts, lists). *The post-lab write-up cannot include any information which is not supported by the Data & Observation section.*

### Before lab coming to lab

* 1. Complete your prelab assignment. At a minimum you must complete write the experimental title, objective, procedure reference, and safety/waste treatment for the experiment prior to the start of the lab period on the day which the experiment is to be done or it will be assume you are not prepared to do the lab and you will be asked to leave the lab until such time as you are prepared. You will not receive extra time for the experiment if you come unprepared.
1. The first page of a new experiment should include the date, experiment name and number to clearly show the start of a new experiment (simply filling out the heading at the top of the page it not enough). The experiment name or number should then be repeated at the top of each page relating to that experiment (use the heading section here).
2. Write a purpose/objective for the experiment.

Three to four sentences introducing and explaining the purpose of the experiment to be performed. Be sure to include the **experimental technique** to be used and determination of unknowns, if applicable. This section should be written in your own words. Occasionally, the goals of the lab work are stated in the body of this background text in the lab manual; but often, the goal are not explicitly listed and must be deduced from a careful reading of the entire experiment. Coming to lab with the goals clearly in mind will also prepare you to carry out the experiment with confidence and efficiently. Copying from the lab manual is plagiarism and warrants a “0” for the assignment.

1. Procedure Reference

Reference procedure using correct MLA/APA format. Be sure to leave space after the procedure reference to note any changes (additions, deletions, etc.) you are instructed to make to the procedure.

It is recommended that you write out your procedures, in your own words, prior to the start of lab to help you understand the experiment better, organize your thoughts, and draw any data tables you will need. However, you are not required to write out the experimental procedure at this point, unless changes are made. It is expected that you will have read through the procedure (more than once) and understand the operations that are involved; it is essential that the student understand why each step is being done.

**Sample references**

Textbook:

Tro, N. (2008).  *Chemistry: A Molecular Approach* (1st ed.), pp. xx-xx. Upper Saddle River, NJ: Pearson  Prentice Hall.

Lab Manual:

Lehman, J. & Olmstead, T. et al (2002).Experiment 1: Computer Warm-Up. In *Grossmont College Chemistry 141 Laboratory Manual* (4th Edition, pp. 1-3). El Cajon, California

Online Lab Manual:

Lehman, J., Olmstead, T. et al (2002). Experiment 1: Computer Warm-Up [Electronic version]. *Grossmont College Chemistry 141 Laboratory Manual*, 1-3.

Online Journal Article, Spreadsheet, or Directions: include author and date if known

Willard, C. (2007). Lab *1 – Error analysis*, Retrieved August 16, 2007, from <http://www.grossmont.edu/cwillard>

Handouts: include author and date if known

Dirbas, J. (2005). “Chemistry 141: Colligative Properties: Molar Mass Determined by Freezing Point Depression” [Handout 2007], Grossmont College, El Cajon, California.

If any published works were used as a source of information in your report (such as the CRC Handbook), these must also be cited.

More guidelines for APA reference style can be found at:
<https://owl.english.purdue.edu/owl/resource/560/01/>

1. Safety and/or Waste Treatment

List the any additional safety precautions or special waste handling procedures called for in the experiment; these are usually given in the lab manual. Be sure to ask your instructor if you have questions.

### During lab

In the working world it is important that detailed instructions of the exact steps (Data and Observations) that you took during the experiment are very important. A legible and complete record of all observations and data collected during the course of the lab period in which the experiment is performed. These notes will lead you to accept or abandon a hypothesis and help you decide the course of future experiments. You must be as objective and honest in recording your observations as you are in making them. Most of the observations and data section can be a narrative description, a story telling what you did and what you saw. Use the first person to make clear that you did the work. If someone else did the work, be sure that point is obvious. If you work in pairs, be sure to note that as well.

Write all observations and data for the experiment in this section. Always record data directly into notebook; do not use scratch paper. Record colors, phases, odors and texture of all substances you observe.

This section is your rough draft for the report. As you record your data and observations, this section may become messy and unorganized which is to be expected. You may want to add a summary of your data in the form of tables, charts or lists to facilitate writing the report rather than trying to "hunt" through disjointed recordings.

1. Data & Observations
* This section should also be written in your own words. Do not copy of the procedure from the lab manual. Use any format you prefer paragraph, a list of procedures/drawings or numbered steps – whatever is easiest for you. Perhaps the easiest way to collect your data and observations is to paraphrase the procedure as you go through the steps and then enter your observations and data for that step.
* Any change to the experiment on the day of the lab should be noted here as well, **along with the name of your lab partner** if you work in pairs.
* New procedures must be meticulously recorded, if you are repeating steps you would simply refer back to where they are already written rather than rewriting them (e.g. repeated steps 3-9 from page 35).
* Draw any equipment used and set up of apparatus if applicable.
* Indicate chemicals used along with amounts.
* This section must be dated and initialed by you and the instructor when you have completed your lab work for the day. For half completed pages sign under the last data recorded so that you may use the remainder of the page for the next lab period. You and a lab mate should also sign and date the bottom of each page containing data before you leave for the day.

The important thing to remember here is that you should theoretically be able to use the instructions in your data and observations section rather than the lab manual to perform the experiment although you may have the lab manual by your side as you complete the lab. Simply enter a one- or two-line statement to describe the operation, and immediately afterwards, record your data. Outline form (rather than complete sentences) is acceptable in this section of your notebook, as it is understood that you will be concentrating on the experiment.

* If you write out your procedures, data tables, etc., in the data and observations section prior to coming to lab a two-column format with the experimental procedures on the left side and your experimental observations on the right is a good way to organize your data and observations:

|  |  |
| --- | --- |
| Procedure  | Data and Observations:  |
| 1. Weigh out approximately 1 g of NH4Cl.
 | 1.0042 g of NH4Cl |
| * 1. Add 5 mL of DI H2O in medium-size test tube to obtain a clear solution
 | Solution is clear and colorless  |
| * 1. Add approximately 1 mL of AgNO3 (aq) into test tube
 | immediate formation of pptppt was white, cloudy no heat observed, no bubbles |

* If you write a running log as you complete the experiment write in reasonably brief, declarative sentences as the work progresses:

Data and Observations:

Step 1 1.0042 g of NH4Cl added to 5 mL of DI H2O in medium-size test tube

 obtained clear solution

 test tube was cold to touch (endothermic process?)

Step 2 approx. 1 mL of AgNO3 (aq) added dropwise to test tube

 immediate formation of ppt

 ppt was white, cloudy no heat observed no bubbles

### After lab

* Review your experimental observations and data. Start analyzing your data this will allow you to recognize if you made an experimental mistake and need to repeat that part of the experiment. If you have questions be sure to ask your instructor. Write down any observations that you did not have time to make during lab.
* Make sure that the header and footer of each page is completely filled out.
* Do not remove any pages from your notebook except for those pages that are turned in with the reports.
* Turn in the original pages (not the copies) with your reports, even if the entire page is a deletion. Your instructor will check that the lab pages you turn in are in numerical order.

# Criteria for Success:

You need to come to lab prepared by completing your prelab and keep accurate and detailed records of your experiment. This will help you when you go to analyze your experimental data for your lab report.

* It must be **complete**. Every detail of your laboratory procedures, results, analysis and conclusions must be recorded so that any individual could repeat the work as you did it.
* It must be **honest**. The details must be recorded immediately after carrying out the procedure, as you first carry out the analysis of the data and as you make observations. Mistakes must be recorded and explained. Bad data must be included along with the good and included in the analysis and conclusions.
* It must be **readable**. Most records are read at one time or another by other individuals. Your notebook may never be neat, but your handwriting and your general organization must be good enough so that other people can interpret exactly what you did.
* Every activity must be **dated**. These activities include mental, as well as physical time spent on the project. Examples include ideas proposed to modify or improve the procedures, design of a follow-up experiment, as well as all thoughts pertaining to the interpretation of the results. Whenever a date is logged into the notebook all entries that follow that date page-wise up until the next logged in date must have occurred on that first date. Within any given day’s pages, the information is generally entered sequentially as it occurs.

Formal Lab Report

# Purpose:

The purpose of writing a lab report is to prepare you to write technical papers for journals, grants for funding, and learn to communicate scientific information to peers and the general public.

# Skills

Lab reports will help you to practice the following skills that are essential to your success in this course, subsequent chemistry courses, and professional life:

* Critical thinking
* Experimental interpretation
* Technical scientific writing

# Knowledge

This document will also help you to become familiar the parts of a formal lab report: title page, objective, introduction, procedure, results and calculations, discussion, conclusion, and post lab questions.

# Tasks:

This document will guide you in writing a lab that includes an objective, introduction, procedure reference, results and calculation section, spreadsheet, discussion and conclusion. You will organize, analyze, and evaluate the data that you collected in lab and create reports for this class.

**A general guide for writing lab reports follows. Each experiment may require modifications of this formal write-up. Some lab assignments may require only a subset of the sections describe below. As your instructor about specific requirements for each lab report.**

### General writing style:

Assume that the audience for your lab report is a scientifically knowledgeable person who is not specifically familiar with this course or with the lab manual. Write your report so that such a person can understand what you did, why you did it, what results you obtained, and what these results mean.

Maintain scientific objectivity in your writing. Stay focused on the facts, evidence, and materials of the lab work. Make interpretations of your results based only on scientific knowledge and logical reasoning. Do not include commentary on your feelings, states of mind, or personal learning achievements. That is not to say that such reflections are not important; rather, that subjective commentary does not belong in the lab report, but elsewhere, such as in a personal learning journal.

### Title Page

Include experiment name, date, your name, your lab partner’s name if appropriate, course number, section number, and your instructor’s name. Your instructor may provide you with a rubric to copy and paste on this page.

### Objective

The objective section should be a brief description (usually no more than one paragraph) of the goals or purpose of the activity or experiment. That is, why are you doing this experiment? To test a hypothesis? To determine a constant? To characterize a sample? In your objective section, briefly mention the technique/method that will be taken to achieve the goals of the lab work. You will have already written an objective for your lab notebook. Now is the time to revise that objective and add any missing experimental goals.

### Introduction

The Introduction should explain the scientific question or problem being addressed by the experiment and how it is to be answer/solved. The Introduction should give background on your lab work: include the theory behind the experiment and an explanation of how the procedure used will accomplish the objective. The reader should be able to understand the logic of the experiment simply by reading this section. The Introduction should include definitions/explanations of important terms, ideas, and concepts; and it should contain any relevant mathematical or chemical equations. A typical introduction should be at least several paragraphs but may run to several pages if required to include all relevant background.

**The introduction will succinctly explain the theoretical basis of the experiment and describe the method that will be used to achieve the objective.** In some experiments, there is very little “theory” that can be discussed, for example, learning about a new lab technique or getting familiar with a particular piece of lab equipment. In these cases, simply describe how the technique or piece of equipment facilitates learning a new skill. However, note that many lab instruments are based on scientific principles and the student must decide whether a theoretical discussion regarding the instrument or its use is appropriate; if in doubt, ask your instructor.

Some lab reports will require a lengthier Introduction. Some examples:

* Qualitative experiments that investigate a particular type of chemical reactivity need to address in the introduction some of the pertinent concepts and theories that are presented in the textbook and in the lecture part of the course.
* Experiments which involve chemical synthesis or the interconversion of one compound into another should include balanced chemical equations for each reaction that is part of the experiment; this should be part of the introduction. Each balanced equation should be labeled (e.g. rxn 1, rxn 2…), so that you may reference the reaction in a latter part of the experiment without rewriting it.
* Experiments that are much more quantitative in nature will require a brief discussion of the mathematical process to be used in calculating the final results; this should be part of the Introduction. Each mathematical equation should be labeled (e.g. eq. 1, eq. 2), so that you may reference the equations in latter parts of the experiment without rewriting it.

In very simple terms:

* Your method description answers the question, “how will the experiment be run?”
* Your theoretical discussion answers the question, “why does this particular method apply to this experiment?”

A well-thought-out Introduction is the key to writing a good lab report; quality is more important than quantity (length).

### Procedure

The only thing that needs to be written in this section is a complete reference (as shown above) for the procedure and any changes that were made to the published procedure. Do NOT type of the experimental procedures that are in the lab manual. Only type experimental procedures that you write yourself.

### Results and Calculations

The results from your experiment are always entered in this section. Recall in the objective that you asked the question, “What is being investigated in this experiment?” This is the place to answer that question**. State your results clearly so the reader knows exactly what happened in the experiment but do not discuss the reasons for your results in this section.**

Tell the reader exactly what you obtained in the experiment, for example: **quantitative results** from an experiment (% composition of a substance) or **qualitative results** (compounds A, B and C were identified as acids; D, E and F were bases).

Whenever you include statistical treatment of your data, which is a result which should be entered in this section.

Calculations (if any) are done in this section. Show all set-ups for each type of calculation; be explicit! If you must perform the same calculation more than once, you do not have to write the set-up for each one, but it should be clear as to which set-up correlates to which calculation(s). Be sure to include the final results of all calculations- consistently highlight your final answers in some fashion, draw a box around the result, double-underline the result or place final results in a table or chart.

It is a good idea to organize your results in a table format to make it easier for the reader to understand the outcome of your experiment. Each table should be numbered (e.g. Table 1: Metal Shot Measurements). If your Data and Observation section has become messy and a bit unorganized, this is the place to “clean it up” and present it to the reader with clarity.

### Discussion

The Discussion is used to present your evaluation and interpretation of your results. Be sure to include quantitative numerical data and qualitative descriptions where appropriate (e.g. The salicylic acid produced was a white, crystalline solid. The percent yield was found to be 91.3%...). In this section, you compare your results to theoretical expectations. Do the results make sense? If they diverge from expectation, state by how much. Evaluate the significance and agreement of your data statistically. Present specific, sound reasons for discrepancies. Did you obtain a result different from your expectations? Do the results call into question your original hypotheses? What questions (raised in your Objective and Introduction sections) have been answered, or remain unanswered in light of your results? Include in the discussion answers to any questions that were posed within the lab manual.

Sometimes the data you obtain in an experiment is straight-forward and self-explanatory. In these cases, your discussion may be brief. However, most of the time, you will need to explain to the reader why you obtained a particular result, especially if your result is different than expected.

The Discussion should also include error analysis (when appropriate): explain sources of error and how errors impact your results. Keep your analysis precise and scientific; don’t resort to vague laundry lists of possible mistakes that might have been made. Be sure to discuss only the connections between error analysis and your actual data and observations.

### Conclusion

Summarize your entire lab report in this section, in one paragraph. State concisely how your results achieved the goals set out in your Objective section. What is the “bottom line”? What is the “take-home message” of the experiment? These should be stated in your conclusion. State your major results in the Conclusion section. If your most important results are captured in a particular set of numerical

### Questions

Check the assignment for any required questions to be answered in the lab report. For some lab reports, the only questions to be answered may be the pre-lab questions. For questions with numerical answers, always show your calculations. These may be handwritten if they involve calculations.

# Criteria for Success:

As scientists, we should strive for specificity and accuracy. As such, I encourage you to avoid vague writing that lacks data supporting your statements. The Grading Rubric for lab Notebooks and Lab Reports gives some general guidelines on thoroughness, supporting information, accuracy, and writing level.

* Start working on your lab reports right away.
	+ Have a rough draft of your lab report several days before the due date. This will allow you time to reflect on your writing and get your questions answered.
* When you get stuck or have questions ask an instructor, a classmate, or a tutor for help.
* Pay close attention to the directions that your instructor gives you for each write-up. Not all laboratory experiments will require each portion of a formal lab report. Your instructor will let you know the expectations for each experiment throughout the semester.
* Turn in your lab reports even if they are not “perfect”. You are going to make mistakes on your lab reports. That is part of the learning process. Pay close attention to the feedback your instructor provides on your lab reports so that you can improve throughout the semester.

### Grading Rubric for Lab Notebooks and Lab Reports

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Thoroughness | Supporting Information | Accuracy | Writing Level |
| “ A” Level Work | All components are complete and directions correctly followed; all questions answerer; all support materials included; information easy to follow; interpretation of results shows true insight into the experiment; went above expectations including information at a high level.  | All supporting materials of extremely high quality; graphs appropriately chosen for data presentation; graphs and data tables well labeled and easy to understand; appropriate graphs and tables included to allow thorough presentation and understanding.  | All content is accurate, including data in graphs, tables, and calculations; very few or minor errors; information is focused and utilizes appropriate scientific concepts and terms. | Excellent writing skills; writing is focused, clear, well organized, and easy to read; correct sentences with few mechanical writing errors; appropriate use of scientific language.  |
| “B” Level Work | Most components present and complete; directions generally followed with minor exceptions; most support materials included; did exactly what was asked for; interpretation of results show some insight unto experiment, but lacks the complete insight of an excellent report. | All materials are well prepared, including well labeled graphs and charts; graphs appropriately chosen for data presentation. | Generally accurate in all major concepts, however there are some minor errors; generally utilizes appropriate scientific concepts in explanations of information. | Good writing skills, generally well organized and readable, but some mechanical errors, some use of scientific language. |
| “C” Level Work | Missing some minor components; some minor support material missing or incomplete; covered what was asked for with some exceptions; errors in interpretation indicate some lack of understanding of the experiment. | Included all graphs and tables, but some minor errors present; graphs and charts do not support information as clearly as possible.  | No major errors, but a significant number of minor errors that indicate either lack of understanding of major concepts or haphazard preparation of the report; scientific concepts utilized in some cases, but not consistently in explanations.  | Level of writing less than what would be expected of a college student; numerous mechanical errors and little use of appropriate scientific language. |
| “D” Level Work | Missing some major components of the report; directions not followed in more than one area; support materials missing or inadequate; major errors in interpretation show lack of understanding.  | Some graphs or tables missing; significant errors in choice of type of graph or in data presentation; information is not well supported by graphs and tables. | At least one major error in interpretation of the experiment in addition to numerous minor errors; generally lacks appropriate use of scientific concepts in interpretation.  | Level of writing far below what is expected of a college student; mechanical errors in writing result in difficult interpretation of scientific concepts; little or no correct use of scientific language.  |
| “F” Level Work | Missing major components of report; directions not generally followed; most support materials missing or incomplete; major interpretation errors show complete lack of understanding of experiment. | Significant graphs or tables missing; significant errors in graphs or tables; data presentation is weak and does not support information. | Numerous major errors in interpretation of the experiment; does not utilize appropriate scientific concepts in interpretation of data.  | Level of writing is unacceptable; writing prevents understanding of scientific concepts; complete lack of use of appropriate scientific language.  |