Lab Notes and Reports

Written communication of laboratory work

Records of laboratory work take at least two forms. These are the **lab notebook** and **technical reports**.

Lab notebook: For legal and reference purposes, the primary record of lab work is the **lab notebook**. The notebook includes notes you make before, during, and after performing an experiment. For grading purposes, we require that you use a commercial notebook with index pages at the front, and numbered, carbonless copy pages for notes. Many introductory chemistry laboratories use suitable notebooks. If your chemistry notebook is otherwise suitable and has blank pages left, you are free to use it for this course. At the end of each laboratory, you will submit the copy pages from your notebook to your teaching assistant. You will submit the copies for any work you do outside of class with the rest of the lab assignment. You will retain the original copies for your record and study. When you fill up one notebook, you are expected to obtain another.

Technical reports: For communication within a broader technical community, lab work is summarized in **technical reports**. These reports communicate your main results and omit many details recorded in your lab notebook. Because the preparation of proper lab reports require considerable time and effort, we will not require a complete report for each laboratory. However, to satisfy UCORE requirements, some formal writing is necessary. For many labs, we will ask that you submit a well written, partial report, where you focus on particular communication tasks.

These two forms of communication employ different standards that can be only partially implemented in an instructional lab. What we require is described below.

Lab notes—official record of attendance and work performed[1]

Although neatness is important, the content of your lab notes is the main criterion for grading. Lab notes must be sufficiently legible to make it easy for you and others to read and understand exactly what you did. Your notes must include all your raw data, and explain how it was analyzed (for instance, using sample equations). You will often type numerical data into Excel spreadsheets for analysis, but the original numbers must appear in your lab notebook as well. *Your notebook is the official record*—and a backup in case your computer crashes. At the end of the semester, you will

[1] A detailed introduction to the lab notebook is found in: Howard M. Kanare, *Writing the Lab Notebook*, (American Chemical Society, Washington, DC, 1985).

take a lab exam in which parts of a few selected experiments are to be reproduced—usually with small changes. You are expected to refer to your lab notebook during the lab exam. (The lab exam is a practical test of your lab notes.) The exam can be relatively easy if your notes are complete. Parts of the exam will be impossible if you omit important details.

With the exception of computer-generated graphs and tables printed during lab, lab notes must be handwritten in pen. Although lab notes are not formal documents, they are legal records. Any attempt to remove information from the record after the fact destroys this value and is considered scientific misconduct. *If you decide that any original data or notes are in error, put a single "X" through it, make short note in the margin explaining why it is in error, then record the new information in a new entry.* Both sets of data must be legible in your lab notes. Your grade will not lowered by including these marked errors. This practice conforms to standard scientific and engineering practice. You are free to work through any derivations that should appear in your lab notes on scratch paper before entering them in your lab notebook.

In case of a dispute over lab attendance or what you did in lab, pages torn from your lab notebook will not be accepted as evidence. Likewise, notes on regular notebook paper will not be accepted as evidence. A computer printout is evidence only if it is permanently attached (taped, not stapled) to an original page in your notebook or shows the signature of the supervising teaching assistant. Missing original pages are evidence for suspicious activity and carry a "presumption of guilt": we will assume you are guilty of something—the only question is what.

If you rewrite or type your notes, understand that your original notes are the official record, not the rewritten notes. Notes made after the fact are not valid records and will not be treated as such. The copy pages with your notes must submitted in order to receive a grade for laboratory work.

Each entry in your lab notebook should start with the current date and time in the left margin. If you work on your lab notes at home after lab, the entries made at home must also begin with the current date and time (the time of writing, not the time of the lab). Each entry must be recorded at the same time the work is performed. Entries must be sequential. Leaving one or more blank pages or part of a page in your notebook for later work is not acceptable. When you move on to a new page, draw a diagonal line through any large blank areas of the previous page. To work on an earlier lab after you have started work on a later lab, start your addition on first blank page in sequence. Mark the top of the new page, "Continued from page ..." and another note at the bottom of the old page, "Continued on page ...". Many lab notebooks provide spaces for these notes. You lab notebook should also have an index for this information.

Unlike lab reports, lab notes do not have formal sections. It is appropriate to write out questions you have about the lab and one or two sentences of introductory material in your notebook before coming to lab; these entries must be dated at the time or writing. Each step of your procedure must be recorded as you actually perform it. Do not copy procedures from the manual into your lab notes before coming to lab. (When pre-recorded procedures are absolutely necessary, draw a vertical line down the center of the notebook page, with your intended procedure on the left and your record of what you actually did on the right.) Likewise you should record your data as you take the data. There is no data section. To help you avoid missing important points, the lab manual includes some questions about each lab; these questions should be answered in your lab notes where the questions arise in the lab. If you print a graph or data table in lab, attach it to your other

notes as close as possible to the handwritten notes that describe the data and how it was collected. Do not collect your computer printouts at the end. Submit your notes in chronological order.

Your lab notes must be sufficiently detailed that you or another student with your background can reproduce your work. The reader must be able to "trace" your work from the original data, through your analysis, to your conclusions. Your notes should leave no doubt about how the data were collected, what sensors and sensor settings were used (if any), and which equations were used to calculate the quantities you report. Define any symbols used in your equations and include appropriate units for numerical data. Sample calculations are often necessary.

Each graph printed during lab should fill a full sheet of paper to allow room for notes. To provide this room, computer-generated graphs should normally be printed in the "landscape" (rather than the "portrait") mode. Landscape mode will print the x-axis along the longer dimension of the paper and thus makes most graphs about 50% larger. In some cases it is useful to display computer-generated graphs, for example, showing position, velocity, and acceleration as functions of time, on the same page to facilitate comparison. These graphs should be printed in the mode that most completely fills the page. All graphs must have a *descriptive* title that indicates what is being graphed. ("Graph 1" or "Exercise 1" is not sufficient.) Labels and units are required for both the x- and y-axes. If you are asked to draw a "curve" through your data points, this should always be a best-fit curve (for example, a straight line if appropriate) that best represents your data. Best-fit lines can be drawn by eyeball and a ruler, or with the help of the computer. If you are asked to calculate the slope (or perform other analysis) of the graph by hand, show the results of this analysis directly on the graph, clearly identifying which points are being used to calculate the desired quantities. When a computer-generated best fit curve is displayed on a graph, the resulting equation (with parameters and uncertainties) should also be displayed on the graph. This allows the reader to evaluate the curve fit results without referring back to the text. Refer to the "Uncertainty/Graphical Analysis Supplement" near the back of your lab manual for more information about using graphs to find mathematical relationships between graphed quantities.

Keeping good records during lab takes time, and it is virtually impossible using formal English, with complete sentences and paragraphs. Record your actions and data in the most clear, efficient way possible. Use phrases instead of sentences. Annotated diagrams—simple sketches with the parts labeled and notes—can save time and be more clear. Descriptive titles for graphs and table columns also help. If an equation is used to describe the data in a graph, write the equation on the graph. Putting it elsewhere usually requires additional text.

Lab reports—formal communication with peers

Although lab notebooks are the primary records of lab work, they are poor communication devices. Experimental results are usually communicated in technical reports. Unlike lab notes, these reports omit most "historical" aspects of the work: false starts are omitted. While one often reports the manufacturer and model number for important pieces of equipment, operational details are usually omitted. (The operational details must be recorded in your lab notes.) While lab notes often include derivations, technical reports normally include only the result. As communication devices, we expect lab reports to conform to the standards of formal written English, with appropriate word choice, grammar, and structure.

Because writing formal lab reports is time consuming, an entire report will not be required for each lab. Rather, most labs will require short writing assignments that focus on one element of an entire report—perhaps an introduction or an experiment section. If the teaching assistant believes a submission is inadequate, the teaching assistant may require that it be rewritten and resubmitted for partial credit. As time permits, we will require complete, formal reports for one or two labs. The deadline for the submission of complete reports will be at least a week after the lab is performed. Your teaching assistant will inform you of the report requirements on a week by week basis.

Lab reports (partial or complete) must be typewritten or printed from a text editor, using the format specified in the "Formal Lab Report Instructions" supplement near the back of the lab manual. You will have the original copies of your lab notes to use in preparing your report. Carbon copies of all relevant lab notes must be submitted to your teaching assistant for credit. The statements and conclusions in your formal report must be supported by the data and analysis in your lab notes. Omissions and gaps in logic, when observed, will lower your grade.

Special requirements for lab assignments

Cover Page

A cover page is required for every submission. It must include:

- The title of the experiment
- Your name and student ID number
- The name of your lab partner
- The date that the lab was performed
- The name of your teaching assistant
- The course and lab section numbers (for example, Physics 101, Lab Section 5)

Nothing else should appear on this page. Lab reports that are submitted in the wrong slot or are otherwise misplaced take much longer to reach your teaching assistant if the information on the cover page is incorrect or incomplete. Work submitted during lab might not require a cover page.

Uncertainty analysis

Many experiments involve a quantitative comparison between values of the same quantity determined by two or more distinct methods. When you compare two values, you must address the question of whether or not they agree within the limits of the expected or measured uncertainties. The Uncertainty/ Graphical Analysis Supplement near the back of your lab manual defines important quantities, such as the standard deviation, and supplies details about determining uncertainties. As the semester progresses, you will need to make decisions by yourself on appropriate methods for calculating the uncertainties in your various measured and calculated quantities. Physics 102 and 202 students are expected to be aware of the uncertainty methods learned in Physics 101 and 201, respectively, and to use them appropriately.