Guidelines for Writing Formal Reports

The results of research generally are shared with other scientists in the form of an article published in a scientific journal. Although scientists often present oral or poster papers at professional meetings, such work usually is preliminary and tentative. When research reaches the point where you can tell a convincing story, then publication in a suitable journal is the appropriate way to share your results.

If you look at several scientific journals, particularly journals from different disciplines, you will see that there are many ways to prepare a research article. Each journal, however, remains true to its format, requiring authors to follow specific guidelines. For this course we will use the structure listed below when preparing formal reports.

- a title
- an abstract
- an introduction
- a procedure
- a discussion of results and conclusions
- notes
- references
- supporting materials

The remainder of this document provides some suggestions for each section of a lab report.[1] *Note: Your electronic notebook and a formal report serve different purposes. In general, copying and pasting the contents of your notebook into your formal report is a poor idea.*

Writing the Title

A good title is brief (15 words or less) and clearly identifies the problem you investigated. Don't use the experiment's title as the title for your report.

Writing an Informative Abstract

A good abstract provides a brief (3-6 sentence) descriptive summary of your report's major finding.[2] At a minimum it should clearly state the goal(s) of your work and a summary of your key result(s), including the expected result(s) when known. Because the abstract summarizes your work, you should prepare it after writing the remainder of the report. For a formal report the abstract is the first thing I read as it provides me with a sense of where to focus my attention. For example, if your results are clearly in error then I will give extra attention to your data, calculations, and experimental design.

Writing a Thorough Introduction

The introduction to your formal report needs to accomplish three things: it should clearly explain how your experiment fits within the broader context of the course's three main topics (i.e. thermodynamics, equilibria, and kinetics), it should explain why your experimental approach is suitable and briefly outline any relevant theory, and it should clearly state the goal(s) of your experiment. Many of these topics are, of course, outlined in the experiment's handout and you may use this as a starting point as you draft your introduction. A good

[1] There are many good texts that cover technical writing. The suggestions compiled here were culled from Porush, D. *A Short Guide to Writing About Science*, Harper and Collins: New York, 1995.

[2] The abstract for the the paper "Can Apparent Superluminal Neutrino Speeds be Explained as a Quantum Weak Measurement?" by M. V. Berry, et. al., and published in the *Journal of Physics A: Mathematical and Theoretical*, particularly short: it simply states "Probably Not." You will want a longer abstract than this!

introduction, however, does not simply repeat information from the experiment's handout; instead, it extends and contextualizes this information. Use the introduction to define terms, to explain basic theory, and to convince me that you understand the experiment's goals. Searching for additional information in the library or on the internet is appropriate and desirable.

Writing a Useful Procedure

This often is the hardest part of a report to write well. Surprisingly, your initial draft will inevitably provide too much detail instead of too little detail! Here are some useful guidelines to consider:

- A procedure is not a list of what you did in lab; it is, instead, a well-written narrative. Avoid using phrases such as "First we. . . " or "Next we. . . ".
- A procedure does not describe the specific things you did in lab; it provides, instead, a general guideline to what you did. For example, you do not need to state that "We evaluated the cooling rate of porridge using initial temperatures of 60°C, 55°C, 50°C, and 45°C," because you will include these temperatures as data in your results and conclusions section. You should state, however, that "The porridge samples used to evaluate cooling rates were heated using a gas stove while stirring with a wooden spoon." Or, you do not need to mention that "We prepared a dilute solution of 2.00×10^{-3} M hemlock by adding 5.00 mL of a 0.100 M stock solution to a 250-mL volumetric flask and diluting to volume with spring water." What is important is the concentration of your final solution of hemlock, not its volume. It is more appropriate to write that "A solution of 2.00×10^{-3} M hemlock was prepared from the available 0.100 M stock solution."
- A procedure does include information on the reagents used in the experiment. Be sure to list all reagents provided for your use or prepared by you (e.g. "Solutions of 6.00 M hemlock and reagent-grade powdered toadstools were used as supplied." or "A solution of 0.10 M hemlock was prepared using the available 6.00 M stock solution and a 5.0 % w/v solution of toadstools was prepared using reagent-grade powdered toadstools.").
- A procedure does include information on the major equipment used during the experiment. Be sure to identify the make and model of the instrumentation and software used to collect and analyze data. Where specific operating conditions are used, be sure to state them (e.g. "Cooling curves for porridge samples were measured using a CelFar thermometer interfaced to a Merlin Microcomputer equipped with a NEWTon data interface. Temperature measurements were made every five seconds until the porridge's temperature reached 30°C.").
- A procedure might mention the type of glassware and minor equipment used in the experiment, but only if the choice is crucial or unusual. For example, if it essential to collect samples of witch's brew using gold-lined sampling bottles, then say so. In general, there is no need to specify the type of glassware as this is made evident by the proper use of significant figures. If your procedure states that you prepared a nominally 0.1 M solution of hemlock, then it is clear that you measured at least one volume using less accurate and less precise glassware, such as a beaker or bottle. On the other hand, if your procedure states that you prepared a 0.100 M solution of hemlock , then it is clear that you used volumetric glassware.
- If your procedure closely follows a previously published procedure, then you may simply make a reference to it and note any significant modifications. Thus, you might write that "The number of plums in a pie was determined using the method of Horner (*13*) with the modification that individual plums were removed using a fork instead of the thumb."

Presenting Your Results and Conclusions

This is the heart of your report so it deserves your greatest attention. The most important requirement of this section is that it is a well-written narrative that clearly guides the reader through a presentation of your data and your analysis of that data. Use tables and figures to organize your data and to enhance its presentation. Be sure that you refer in your narrative to each table and figure and guide the reader to the specific point(s) of information contained within each. Remember that your goal is to make a convincing

argument about the analysis of your data and to arrive at specific conclusions that are well-supported by your data. Don't leave this to your reader! Finally, be sure to evaluate the reasonableness of your results. If you know the expected results for the experiment, then compare them to your conclusions and discuss possible sources of error. *When discussing sources of error do not cite "human error" as you may assume that you correctly used your equipment*; instead, consider other sources of errors that might reasonably account for the magnitude and the direction of your error.

Making Using of Notes

There are two important aspects of your report—derivations and calculations—that you may wish to include, but whose presence detracts from a smoothly written narrative. To include this material without distracting the reader, place it in a note appended to the back of the report. For example, you might write the following: "Assuming that breaking a standard hand mirror causes seven years of bad luck, we know that Sleeping Beauty's step-mother can expect an additional 23.6 yrs of bad luck (Note 1)." In the note you can then work through the relevant calculation.

Referencing Other Works

Every discipline has its rules for preparing references. In most chemistry journals references are cited in the text using italicized numbers listed within parentheses—for example, citing the first reference as (*1*)—or using superscripts. References are placed either at the bottom of the page where the reference is made or collected, in numerical order, at the end of the report. Use the following standard formats:

- Journal articles: Green, A.; Scarlet, R., "Preliminary Measurements on the Strength of Huts Made Using Bricks: Can They Withstand the Huffs and Puffs of Wolves?" *Folk Tales Sci.*, **2003**, *45*, 313-315.
- Books: Blue, V. *A Brief History of Magic Potions*, Merlin Press: Salem, MA, 1999.
- Chapter or article in book with editor: White, B., "Seeking a New Means for Spinning Straw into Gold" in *Studies in Alchemy*, Black, C., ed., Merlin Press: Salem, MA, 2001.
- Internet sites: http://www.goldilocks.com/mattresshardness/ (accessed August 2014).

Supporting Materials

Inevitably you will gather more data than you need to include in your report. Use this section to list additional tables and/or figures that support your work and that you wish me to examine (as needed). Place these materials in a folder labeled "Appendix" and place it in the experiment's folder included within your group's Dropbox folder. Include in your lab report a brief outline of what supporting information is in the appendix.

Stylistic Considerations for Scientific Writing

Grammar, spelling and formatting matter, as does well-written prose. Expectations for the quality of your writing for this course are no different than that for courses in the humanities or social sciences. A few specific suggestions are provided here:

- Be concise. Use simple words. Write short sentences. Thermodynamics, equilibria, and kinetics are complicated enough; there is no need to make them more complicated by writing confusing, wordy sentences.
- Remember the basic rules for writing a good essay. Introduce a paragraph's main idea with a topic sentence and develop the idea throughout the remainder of the paragraph. Link your paragraphs together with smooth transitions.
- Words have specific meanings. This is particularly important in scientific or technical writing. Although rate and energy, for example, have many definitions, in the context of this course their meanings are very specific. Be sure you use terms correctly.

- Numbers have significant figures and units. You know this, so use them properly. In scientific writing the use of significant figures carries meaning. When you say that "A 0.127 g portion of dried toadstools was reacted with. . . ," providing three significant figures tells the reader that you measured the mass using a balance with three decimal places. If the same statement simply said "0.1 g of dried toadstools" the reader will assume you simply used an approximate means to measure out the sample, such as the amount that fits on the tip of a spatula. While on the subject of numbers, a decimal point is placed between numbers; the decimal equivalent of $\frac{1}{2}$ mL is 0.5 mL, not .5 mL. Finally, if you must begin a sentence with a number, write out the number; thus, write write "Five liters of hemlock were obtained." instead of "5-L of hemlock were obtained."
- Use captions, legends, and footnotes to explain the contents of figures and tables. Even though you will discuss a figure or table in your narrative, a caption helps focus the reader's attention. Figures that contain more than a single set of data must include a legend that identifies the data sets, which you can incorporate into the caption or embed in the figure. Make use of footnotes in tables to add helpful annotations.
- Sequentially number equations included in your narrative. The appropriate format is to center the equation on its own line (rather than including the equation in the middle of a line of text) and place a numerical label at the right margin; thus

$$PV = nRT \tag{1}$$

Rather than retyping the equation later, you can simply refer to it by its number. For example, "Rewriting equation (1) as. . . ".

I'm Suffering From Writer's Block! How Do I Get Started?

Preparing a formal lab report is a daunting task. Here are some suggestions on how to start. Begin by thoroughly organizing and analyzing your data. As you do this, you likely will create a variety of tables and figures; cull through these and select those that most efficiently summarize your data and results and that are most crucial to your conclusions. Next, write the narrative for the results and conclusions section, building it around your tables and figures. Write the procedure section after you complete the results and conclusions section. As you write your procedure, focus on ensuring that another student in Chem 260 could explain how the data presented in the results section were obtained. Finally, write your abstract at the very end.

What about the introduction? You can write this at any point as it is independent of your procedure, data, and results (although it does define the problem on which you were working). You might even (gasp!) want to begin working on your introduction while you are preparing for your work in lab.