Some Guidelines For Preparing a Formal Report

The results of laboratory work generally are shared with other scientists in articles written for scientific journals. Although scientists often present oral or poster papers at professional meetings, such work is usually preliminary and tentative. When research reaches the point where a convincing story can be told, then publication in a suitable journal is the appropriate way to share your results.

If you look at a variety of scientific journals you will find that there are many formats for research articles. Each journal, however, remains true to its format, most of which include the following items and sections: a title, an abstract, an introduction, a procedure, a discussion of results and conclusions, references and notes, and appendices. Although these items usually are a part of any research article, some journals combine them in different ways. For example, it is not unusual for the results and conclusions to be in separate sections.

For the purposes of this course we will use the format listed above for formal reports. The remainder of this document provides some suggestions for each section of a lab report.[1] Note: Your electronic notebook and a formal report have different purposes. In general, copying and pasting the contents of your notebook into your 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. At a minimum it should clearly state the goal(s) of your work, the key technique(s) used, 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. Or, if your description of the experiment's purpose is confusing then your understanding of the experiment may be weak; in this case I will give extra attention to your introduction.

Writing a Thorough Introduction. The introduction to your laboratory report should 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 issues are, of course, outlined in the experiment's handout and you may use this as a starting point when drafting your introduction. A good introduction, however, will 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 efforts will inevitably provide too much detail instead of too little detail! Here are some useful guidelines to consider:

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

- A procedure is not a list of what you did in lab; it is, however, 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 does, however, provide 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 hemlock solution, 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 provide 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 provided 6.00 M stock solution and a 5.0 % w/v solution of toadstools was prepared using reagent-grade powdered toadstools.").

- A procedure does provide 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 specify 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 a nominally 0.1 M solution of hemlock was prepared, then it is clear that volume measurements were approximate (e.g. a graduated cylinder and a bottle or beaker). On the other hand, if your procedure states that a 0.100 M solution of hemlock was prepared, then it is clear that volumetric glassware was used.

- 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 must be 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 the reader! Finally, be sure to evaluate the reasonableness of your results. If you know

the expected results for the experiment, then compare your conclusions to them 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.

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 (e.g. (*1*)) or as superscripts. References may be 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).

Making Using of Notes. There are two important aspects of your report—derivations and calculations—that frequently should be included, 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.

Appendices. 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). The tables and figures should be gathered together in a folder labeled "Appendix" and placed within 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.

Verifying Your Work. Most of the time your results will be reasonable; that is, the data you collect and the results you report are within expectations even if they have more uncertainty than your might desire. When your results are at odds with expectations, however, it may be because of lousy data or good data that are incorrectly analyzed. Between your results and conclusions section, your notes and any supporting information in your appendix, it must be possible for me to reconstruct your work. If I can't, then several areas of your report are likely to be judged unacceptable.

Stylistic Considerations for Scientific Writing. Finally, grammar, spelling and formatting matter, as does well-written prose. *The quality of your writing in this course should be 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 tough enough to understand; 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. Rate and energy, for example, have many definitions, but in the context of this course their meanings are very specific. Be sure you use them 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…," listing three significant figures tells the reader that the mass was weighed on a balance with three decimal places. If the same statement simply said "0.1 g of dried toadstools" the reader would rightly assume that the experimenter simply used an approximate means of measuring the sample, such as the amount fitting on the tip of a spatula. While on the subject of numbers, a decimal point is placed between numbers; the decimal equivalent of ½ is 0.5. Writing 0.5 as .5 can be confusing to the reader, who may not notice the decimal point and believe that the value is 5. Finally, if you must begin a sentence with a number, write out the number; thus don't write "5-L of hemlock were obtained"; instead, write "Five liters 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 containing more than a single set of data should include a legend identifying the data sets, either incorporated into the caption or imbedded 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 in brackets at the right margin; thus

$$PV = n\mathrm{R}T \qquad [1]$$

  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 can be a daunting task. Here is a suggestion on how to get started. 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 as you begin preparing for the lab.

How Does a Group Write a Report? Your reports are a group effort. It is worth considering, therefore, how a group might work together to produce a quality report. One approach is to assign one group member the task of preparing an initial draft on which the remaining group members can comment. This first draft is then rewritten and reviewed again (and again, as needed).

A second approach is to divide the report into three or more parts, with each member taking responsibility for one or more parts. An obvious way to divide the report is into the introduction, the procedure, and the results and conclusions. The advantage to this approach is that the workload is more equitable. This approach, however, often leads to reports that read poorly due to differences in writing styles, that become repetitive because information is repeated in three places or that omit important information because each group member thinks that the others will include it when writing their sections.

Regardless of the approach your group decides to use, the three most important thing you can do to ensure a well-written and thorough group report are:

- *Don't procrastinate!* Get an early start on your writing so you have ample time to conduct any necessary research, to completely analyze your data and to give others a chance to read through and comment upon your work. Agree on intermediate deadlines and keep to them.
- *Write multiple drafts!* Prepare an initial draft for yourself and edit it before preparing a second draft to share with your group. Incorporate their comments into a third draft, which should then need only minor corrections before preparing the final report.
- *Remember that your report is a collaborative effort!* Don't become so enamored of your prose or your ideas that you find it difficult to listen to the ideas of other group members. Share ideas with each other and maintain an open mind.