Colby

Chemistry Independent Research Expectations

The Department of Chemistry at Colby College is firmly committed to providing significant independent research opportunities to all our students. Independent research is often the first time that our science majors will actually do real science. Independent research reinforces our classroom instruction, teaches new techniques, and requires students to develop time management skills, perseverance, and work in a research group. Research is a wonderful intellectual experience and can be a lot of fun.

Independent research requires a significant time commitment by both the students and the faculty. It is also important that the expectations for student research be clearly articulated to every student at the start of the research project. All students conducting research must complete the departmental safety program before the start of research. Students are expected to be neat and respectful of laboratory spaces and instrumentation. Students may get paid for independent research or receive academic credit, but not both. For students receiving academic credit, a departmental committee will determine all independent research grades at the end of each semester (or academic year, in the case of Senior Honors). The guidelines used in evaluating independent research are as follows:

- *Time invested*
  You are expected to work 4 hours in the lab weekly per credit hour of graded research during the semester. Your lab time will be gauged via your lab notebook at the end of each semester. We expect to see a minimum of 12 notebook entries per credit hour (an average of one per week per credit hour). It is likely that you may have clusters of entries as you work on an experiment and then some time in between entries. Make sure that you well document each experiment, not only so that you or someone else could follow your work, but also so that you receive credit for your work.

- *Quality of work*
  While we understand that experiments are often unsuccessful, we expect to see some sort of progress in your research. Keep in mind that even a negative result can benefit the project as a whole.

- *Observation of proper safety procedures*
  It is critical that you observe proper safety procedures, both for your own safety and for everyone else's. You must wear proper attire (closed-toe shoes, safety goggles, and, when appropriate, gloves). Keep in mind that gloved hands should not leave the lab because of possible contamination. Spilled chemicals, dirty dishes in the lab, and unlabeled solutions can also contribute to an unsafe working environment. If members of the department have to

repeatedly warn you about unsafe working practices, then your grade will be reduced accordingly.

- *Research report*
  In addition to your lab notebook at the end of the semester, you are required to submit a research report, describing your goals, your methods, and your results. The length of this report should be approximately 5 pages/credit-hour, and it is due to your research advisor on the last day of classes. Note that the time spent writing the research report does not count towards the 4 lab-hours/credit-hour time commitment. General guidelines for preparing a research report appear on subsequent pages of this document. Consult with your research advisor for specific requirements for your group. Note that an abstract is not necessary for your departmental independent research report.

Please sign and return this page to your research advisor to acknowledge that you have read and understand the expectations for independent research as outlined in this document. Your advisor should receive this completed form by the end of the first week of classes.

Signature_____ Date_____

Preparing A Research Report

GENERAL RECOMMENDATIONS

An excellent resource is "Guidelines for Preparing a Research Report" published by the ACS Committee on Professional Training (CPT)[1] and reprinted here. In addition, we recommend the following articles for some guidelines on scientific writing styles:

- For a more complete listing and examples of good scientific grammar and writing styles: Potera, Carol (1984) The basic elements of writing a scientific paper: The art of scientific style. *J. Chem. Ed. 61*, 246.
- A great list of suggestions for a successful scientific writing process -- including a section that emphasizes the importance of outlining before writing: Eisenberg, Anne (1982) Strategies five productive chemists use to handle the writing process. *J. Chem. Ed. 59*, 566.
- For some good guides to scientific writing style and for a brief description of the common sections of a research paper: Spector, Thomas (1994) Writing a scientific manuscript. *J Chem. Ed. 71*, 47.
- For great examples of common mistakes in scientific writing: Bunting, Roger (1999) Precise writing for a precise science. *J. Chem. Ed. 76*, 1407.

GUIDELINES FOR PREPARING A RESEARCH REPORT

Research experience is as close to a professional problem-solving activity as anything in the curriculum. It provides exposure to research methodology and an opportunity to work closely with a faculty advisor. It usually requires the use of advanced concepts, a variety of experimental techniques, and state-of-the-art instrumentation. Ideally, undergraduate research should focus on a well-defined project that stands a reasonable chance of completion in the time available. A literature survey alone is not a satisfactory research project. Neither is repetition of established procedures. Research is genuine exploration of the unknown that leads to new knowledge which often warrants publication. But whether or not the results of a research project are publishable, the project should be communicated in the form of a research report written by the student. It is important to realize that science depends on precise transmission of facts and ideas. Preparation of a comprehensive written research report is an essential part of a valid research experience, and the student should be aware of this requirement at the outset of the project. Interim reports may also be required, usually at the termination of the quarter or semester. Sufficient time should be allowed for satisfactory completion of reports, taking into account that initial drafts should be critiqued by the faculty advisor and corrected by the student at each stage. Guidelines on how to prepare a professional-

[1] http://www.chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=education\cpt\ts_rrguide.html (accessed 8/24/06)

style research report are not routinely available. For this reason, the following information on report writing and format is provided to be helpful to undergraduate researchers and to faculty advisors.

Organization of the Research Report

Most scientific research reports, irrespective of the field, parallel the method of scientific reasoning. That is: the problem is defined, a hypothesis is created, experiments are devised to test the hypothesis, experiments are conducted, and conclusions are drawn. This framework is consistent with the following organization of a research report:

- Title
- Abstract
- Introduction
- Experimental Details or Theoretical Analysis
- Results
- Discussion
- Conclusions and Summary
- References

Title and Title Page

The title should reflect the content and emphasis of the project described in the report. It should be as short as possible and include essential key words. The author's name (e.g., Mary B. Chung) should follow the title on a separate line, followed by the author's affiliation (e.g., Department of Chemistry, Central State College, Central, AR 76123), the date, and possibly the origin of the report (e.g., In partial fulfillment of a Senior Thesis Project under the supervision of Professor Danielle F. Green, June, 1997). All of the above could appear on a single cover page. Acknowledgments and a table of contents can be added as preface pages if desired.

Abstract

The abstract should, in the briefest terms possible, describe the topic, the scope, the principal findings, and the conclusions. It should be written last to reflect accurately the content of the report. The length of abstracts varies but seldom exceeds 200 words. A primary objective of an abstract is to communicate to the reader the essence of the paper. The reader will then be the judge of whether to read the full report or not. Were the report to appear in the primary literature, the abstract would serve as a key source of indexing terms and key words to be used in information retrieval. Author abstracts are often published verbatim in Chemical Abstracts.

Introduction

"A good introduction is a clear statement of the problem or project and why you are studying it." (The ACS Style Guide. American Chemical Society, Washington, DC, 1986.) The nature of the problem and why it is of interest should be conveyed in the opening paragraphs. This section should describe clearly but briefly the background information on the problem, what has been done before (with proper literature citations), and the objectives of the current project. A clear relationship between the current project and the scope and limitations of earlier work should be made so that the reasons for the project and the approach used will be understood.

Experimental Details or Theoretical Analysis

This section should describe what was actually done. It is a succinct exposition of the laboratory notebook, describing procedures, techniques, instrumentation, special precautions, and so on. It should be sufficiently detailed that other experienced researchers would be able to repeat the work and obtain comparable results. In theoretical reports, this section would include sufficient theoretical or mathematical analysis to enable derivations and numerical results to be checked. Computer programs from the public domain should be cited. New computer programs should be described in outline form. If the experimental section is lengthy and detailed, as in synthetic work, it can be placed at the end of the report or as an appendix so that it does not interrupt the conceptual flow of the report. Its placement will depend on the nature of the project and the discretion of the writer.

Results

In this section, relevant data, observations, and findings are summarized. Tabulation of data, equations, charts, and figures can be used effectively to present results clearly and concisely. Schemes to show reaction sequences may be used here or elsewhere in the report.

Discussion

The crux of the report is the analysis and interpretation of the results. What do the results mean? How do they relate to the objectives of the project? To what extent have they resolved the problem? Because the "Results" and "Discussion" sections are interrelated, they can often be combined as one section.

Conclusions and Summary

A separate section outlining the main conclusions of the project is appropriate if conclusions have not already been stated in the "Discussion" section. Directions for future work are also suitably expressed here. A lengthy report, or one in which the findings are complex, usually

benefits from a paragraph summarizing the main features of the report - the objectives, the findings, and the conclusions. The last paragraph of text in manuscripts prepared for publication is customarily dedicated to acknowledgments. However, there is no rule about this, and research reports or senior theses frequently place acknowledgments following the title page.

References

Literature references should be collated at the end of the report and cited in one of the formats described in The ACS Style Guide or standard journals. Do not mix formats. All references should be checked against the original literature.

Preparing the Manuscript

The personal computer and word processing have made manuscript preparation and revision a great deal easier than it used to be. Students should have the opportunity to use a word processor and have access to graphics software which allows numerical data to be graphed, chemical structures to be drawn, and mathematical equations to be represented. These are essential tools of the technical writer. All manuscripts should routinely be checked for spelling (spell check programs are helpful), and all manuscripts should be carefully proofread before being submitted. Preliminary drafts should be edited by the faculty advisor before the report is presented in final form.

Two Useful Texts

Writing the Laboratory Notebook, Kanare, Howard M., American Chemical Society, Washington, DC, 1985.

This book describes among other things the reasons for note keeping, organizing and writing the notebook with examples, and provides photographs from laboratory notebooks of famous scientists.

The ACS Style Guide, Dodd, J. S., Ed; American Chemical Society, Washington, DC, 1997.

This volume is an invaluable writer's handbook in the field of chemistry. It contains a wealth of data on preparing any type of scientific report and is useful for both students and professional chemists. Every research laboratory should have a copy, and it should be as accessible as the Handbook of Chemistry and Physics. It gives pointers on the organization of a scientific paper, correct grammar and style, and accepted formats in citing chemical names, chemical symbols, units, and references. There are useful suggestions on constructing tables, preparing illustrations, using different type faces and type sizes, and giving oral presentations. In addition, there is a brief overview of the chemical literature, the way in which it is organized and how information is disseminated and retrieved. A list of other excellent guides to technical writing is also provided.