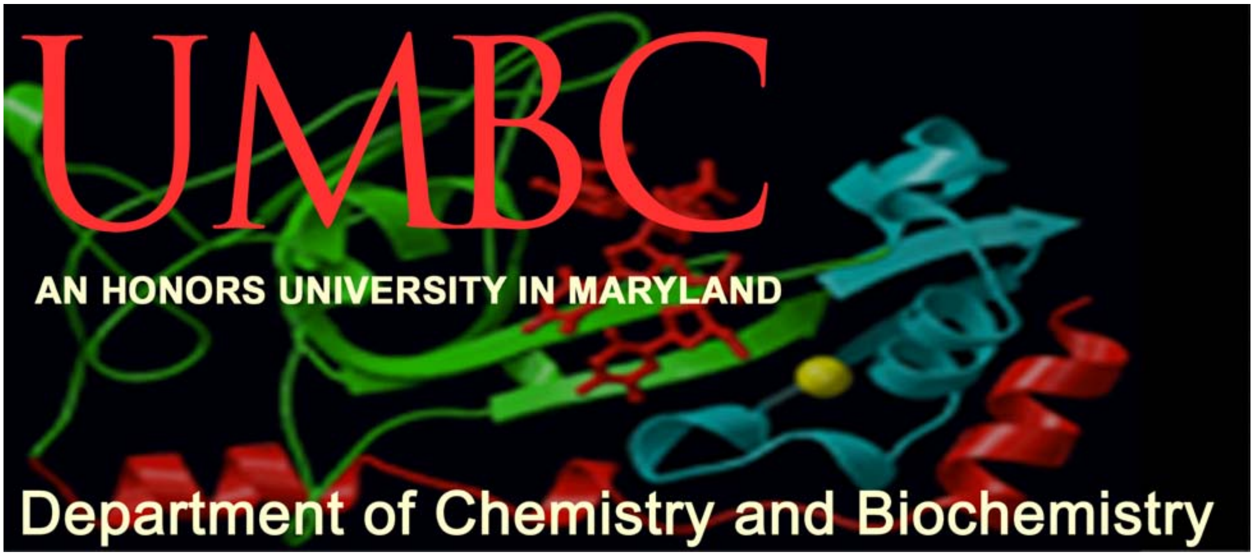

DEPARTMENTAL WRITING AND RESOURCE GUIDE

Writing in the Discipline Committee, Department of Chemistry and Biochemistry

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I. INTRODUCTION.

Most of us are driven into the world of science by intrinsic curiosity, asking "why" and wanting to engage in activities to find the answers. We learn about "the scientific method" (see below) of tackling a research problem and, in formal laboratory and lecture courses, are taught the mechanics to carry out the required experiments. Learning these skills is an important aspect of becoming a successful scientist. Of equal, if not greater importance, is developing the skills to build on the knowledge of others and share your findings with the scientific community. No discovery can be great if it is not accurately and concisely disseminated to the world. In this context, it is crucial to develop technical writing skills that conform to the standards put forth by the scientific community being addressed. Just as you expect to see certain standard formats when you open everyday resource books as simple as a telephone book, the scientific community expects to see your findings reported in a standard way.

Acquiring scientific writing skills goes well beyond a grammatically correct document. The most difficult task faced by students is developing the correct scientific style, specific to a given writing task. In addition, to do scientific research, one must (i) learn how to use data gathering resources to search the literature and make sure the work or interpretation of the work is unique (it's never good to report something as unique that was done years ago and it sure can save you a lot of time if you don't "reinvent the wheel!"); (ii) develop thorough and accurate note-taking skills, as you are responsible to prove anything you claim you have done; and (iii) report your findings in technical reports, peer-reviewed manuscripts, or as a presentation at a scientific conference. While there are, admittedly, variations in how each of these tasks are carried out, depending upon your sub-discipline, there are accepted standards and recommended formats that are used.

The purpose of this Guide is to itemize many of the writing tasks that you will be faced with during your undergraduate and graduate education as well as beyond. You will encounter one or more of these tasks in the courses you take, as well as in independent research that you may be involved in. For each task, a recommended format will be presented, along with tips and guidance on do's and don'ts. It is important to note that each professor may require some deviations from the recommended formats given in this guide. Such instruction should always be followed in submitting your assignments.

In summary, it is crucial to use your time at UMBC to develop your technical writing skills in all aspects of your education. Regardless of the career path you choose, you will be expected to communicate science, both in a written and oral fashion, to your peers, as well as less scientifically trained individuals! This is a skill that is acquired by reading examples, creating your own works, and obtaining feedback from your peers and instructors. A bibliography listing some potentially useful references is included at the end of this writing guide.

II. CONSTRUCTING A PARAGRAPH.

The bedrock of successful written communication in science is the employment of proper paragraph structure, the foremost element of which is the topic sentence. In almost all cases in scientific writing, with the few exceptions discussed later, the paragraph begins with the topic sentence. The topic sentence tells the reader the single main point that is to be elaborated in the remaining sentences in the paragraph; it also summarizes the nature of the contents within. Because science is generally complex, writing with the reader foremost in mind is a good guiding principle in developing a paragraph, and constructing an appropriate topic sentence helps the reader understand clearly what (s)he is supposed to be 'coming away with' while reading what is in the paragraph. A topic sentence is also a metric for the writer: if you are in the middle of thinking about something, or constructing a sentence about something, that is not immediately germane to the topic sentence you have constructed, then it belongs elsewhere. It can be included in a different paragraph, or may be its own topic sentence. That is a matter that can be set aside and dealt with after the paragraph at hand has been concluded.

A few examples of topic sentences are illustrative.

1. GOOD example 1. 'The infra-red spectrum contains four absorption bands that indicate three distinct functional groups are present in the unknown; a carboxylic acid, a nitrile and a benzene ring.' One knows immediately what the main point is and what evidence pertaining thereto is going to be discussed. Such a direct declarative sentence exhibits the qualities alluded to above. For the novice reader, (s)he is being taught what qualities of the infrared spectrum serve as signpost for the given functionalities. The expert spectroscopist will probably read the sentence, jump immediately to view the included spectrum, say 'yep, you got it' and move on to the next paragraph without bothering to read the rest of the paragraph. If (s)he disagrees after viewing the spectrum, (s)he will probably return to your paragraph and go over your analysis closely to resolve the differences – in your favor of course! This topic sentence is also useful for you as a writer. Having that sentence means you are focusing on the IR in this paragraph, and the sentence you wrote about what the ^{1}H-NMR spectrum says about a carboxylic acid belongs in a different paragraph. This doesn't of course preclude you from developing your analysis in a different way in which you discuss IR and NMR in the same paragraph, but this must be done under a different topic sentence that unifies them, as in a similar situation in the next example.

2. Good example 2. 'Both the ^{13}C-NMR and infrared spectra provide definitive evidence for the presence of a benzene ring in the unknown.' Again, as a reader, the message to take be taken away from this paragraph is quite clear. For the writer, it means the material about the aforementioned carboxylic acid and nitrile functionalities **(see 'Good example 1')** will be grouped in another paragraph or other paragraphs.

3. BAD example 1. 'The Grignard reaction is a highly important reaction in organic chemistry.' The reason this is a problematic sentence is most easily appreciated from the reader's point of view. Having read it, the reader has no idea what the paragraph is going to be about. It is hopefully going to focus on the Grignard reaction, but the word 'important' is left to the imagination. Are we going to read about its economic importance, its historic

significance, or its importance in the framework of a host of carbon-carbon bond forming reactions or lastly perhaps in the scope of synthesis of alcohols? None of these is an improbable topic – even in organic chemistry journals, one comes across discussions of historical and economic significance, particularly in “Introduction” sections. An improved topic sentence might read “The Grignard reaction is an important method for forming carbon-carbon bonds in organic chemistry.”

All remaining sentences in the paragraph are subordinate to and elaborative/supportive of, the single main point summarized in the topic sentence. In this manner, the properly constructed paragraph is analogous to a pyramid: the topic sentence is the pinnacle supported by the substructure, the foundation elements.

Writing an appropriate paragraph really is as simple as paying strict attention to the few principles above, but a few techniques may be helpful.

Construction of an outline for a single paragraph is sometimes useful for organizing your presentation. The thought of making an outline for every paragraph in a paper is probably frightening. You won’t need to. Just going through this exercise in a few cases where you are finding it difficult to generate the paragraph will let you make the connections and disentangle the disconnections. After some practice, you will shortly find that you rarely need to do this – it is surprising that this exercise seems to help make ‘neural connections’ that allow you to begin to instinctively structure proper paragraphs. An example of a paragraph outline, borrowed conceptually from the *Prentice-Hall Handbook for Writers*, is given below. It is obvious that such a paragraph would be pretty boring, but it illustrates some important points. Sub points A and B are strictly in line with the topic sentence which will be some grammatically correct sentence concerning ‘US Coinage equal to one-fourth of a US dollar’. In Sub point C, the writer is beginning to wander off into something that may be quite important to the writer, and perhaps to major themes in the paper, but it has little to do with the tightly constructed topic sentence and preceding subpoints. Subpoint C needs to be yanked from this paragraph and placed in its own paragraph, subsequent to the writer figuring out how it bears on the major themes of the paper.

I. US Coinage equal to one-fourth of a US dollar

- A. Single Coin – a quarter
- B. Combinations of coins
    - 1. Dime and nickel combinations
        - a. two dimes and a nickel
        - b. a dime and three nickels
        - c. five nickels

2. Combinations including pennies

    a. 25 pennies

    b. any of the several combinations of dimes, nickels and pennies that equal 25 cents.

C. Coin operated machine recognition of one-fourth of a US dollar – many give change so don't require 25 cents

1. quarter, no change

2. three dimes, get back a nickel

3. pennies are not usually accepted

An alternative method that is sometimes quite useful, particularly at times of 'writer's block', is to just 'get it down on paper' (or keyboard) and piece it together afterwards. Warning: this method requires an equal measure of discipline. This technique reminds the author of an evening spent looking for drinks and dinner in York, England on the way up to a meeting at Newcastle from London. In one case, it was possible to figure out what food a pub was serving by examining the stomach contents of a drunk laying at the doorstep of the pub. Foregoing the eggs and sausage, another pub was chosen. The alternative method appears to be quick and easy, you write down a lot of things that you think are relevant to the 'point', something that in fact is not very clear in your mind, and then figure out what you are trying to say. You do this one paragraph at a time. As you finish the paragraph, you examine its contents. You may find the real point, the topic sentence, is buried in there, in the third sentence down, maybe with a minor modification. You cut and paste that to the top, it becomes the first sentence in the paragraph and is a guidepost or sieve for the rest of what you have written. Some of the remaining text/sentences will be relevant and you can rearrange as you prioritize, and some will be irrelevant or more relevant to another 'theme', really another topic sentence. The danger in this method is that if you are not diligent, you will skip the 'examination' phase, erroneously confident that your point will get across. Get that notion out of your head. If what you are talking about is even mildly complex, the paragraph must adhere to the simple rules elaborated above – keep the pyramid foremost in mind.

Exceptions to Topic Sentences

The two exceptions to the requirement for the topic sentence at the beginning of every paragraph are in the construction of an Abstract, discussed elsewhere, and in the very first paragraph of a paper. The allowance for this exception is based on the desire to command the attention of the broadest possible readership to which what you want to 'say' is relevant. Thus the very first paragraph can be constructed as an inverted pyramid, in which one begins with a wide-ranging description of significance or impact or historical perspective of the general topic area and gradually focuses down to what of significance will be addressed in the coming document.

All writing assignments (with the exception of filling in the blank or short answer questions) require you to write individual paragraphs. The guidelines for paragraph construction given above are to be **universally** followed.

III. DEVELOPING AN OUTLINE.

In all cases, when you are presented with a lengthy writing assignment, such as a laboratory report, literature review, or research report/paper, it is useful to start by preparing a detailed outline. The outline should have subsections:

I. Main section (e.g. Introduction, Experimental Methods, …)

- A. Sub-section 1 (collection of paragraphs that discuss related ideas)
  1. Key idea in paragraph 1
     - a. Components of paragraph 1
       …
  2. Key idea in paragraph 2
     …
- B. Sub-section 2 (collection of paragraphs that discuss related ideas)
  …

Such an outline is extremely important for organizing key ideas, maximizing logical flow of the ideas, improving the precision of your writing, and preventing redundancy in your work. Use clearly labeled sections (i.e., headings/sub-headings) and sub-sections generously. This helps the reader follow and organize what you are presenting as (s)he reads. In all cases, be sure you take on a writing task in a piece-wise fashion. After you have decided on the key ideas and their order, develop each idea into a paragraph or set of paragraphs. Be sure that all sentences supporting the key idea are collected together in the same paragraph and that related paragraphs follow on each other in a logical and coherent manner. Finally, be sure to follow the simple rules for **writing a paragraph**, described in Section II. This outline will help you take on even the most intimidating writing task in a section-by-section way. It is unreasonable to expect to simply sit down and write a large document in one sitting.

IV. GENERAL GUIDELINES FOR ANSWERING A FREE RESPONSE QUESTION.

You will encounter short answer questions in more places than you realize. In their simplest form, you will be asked to provide brief, short sentence or phrase, answers to a very specific question. More advanced exercises will ask you to compose a short essay or paragraph response to address a specific topic. In all cases, a clear and concise (= brief) response will receive the highest point value in a grading scheme; brevity is the key. Be sure you CONCISELY AND THOROUGHLY answer the question at hand … no more, no less. Many students make the mistake of meandering about, or “regurgitating” everything they know in trying to answer a question. In this fashion, they may never really answer the question. You can expect to get zero credit for a response like this, regardless of how much you write!

SHORT ANSWER: In tackling short answer or essay questions, pay attention to the following verbs that are likely contained in the question:

(1) *compare:* find and discuss the similarities between two or more items and discuss them;

(2) *contrast:* find and discuss the differences between two or more items and discuss them;

(3) *define:* provide a concise definition, not an essay;

(4) *explain:* provide a clear, logical argument, based on relevant supporting evidence, for “why” a specific fact or observation is true.

Depending on which of these (or other) verbs are contained in the question, you must answer in an appropriate fashion. No matter what, be sure you answer the question! As an example, if you are asked a question such as “What is the nature of x?” your answer should begin “The nature of x is … “ This statement should be followed by the presentation of supporting evidence to support your statement.

ESSAY QUESTIONS: When presented with an essay question, you will have to invoke more of your own creative thought and organization. It is useful to spend approximately the first 1/3 of your time writing down the key ideas that you will include in your response. Each idea should correspond to the nucleus of a topic sentence for a stand-alone paragraph in your essay. The ideas/paragraphs should flow in a logical and cohesive order. In the remaining time, write the essay by taking each idea, one at a time, and composing the paragraph. Be sure there is flow between your paragraphs.

V. GENERAL GUIDELINES FOR KEEPING A LABORATORY NOTEBOOK

In your laboratory classes, you will be given detailed procedures on how to set up and conduct the experiment. It is important that you view these procedures as the intended way of conducting the experiment. As you carry out the experiment, you must write down every detail and what you actually did. If the experiment or lab did not go as planned, detailed record-keeping will be a valuable resource in understanding what happened. As you progress towards independent research, you will frequently be modifying published procedures and figuring out how to make something work or work better. In these cases, it is crucial to keep careful notes so that you or others can reproduce the experiment when it does work. The best discoveries arise from the unexpected, so make sure they get documented!

V.A General Requirements. Each laboratory notebook must:

(i) Be bound (you are encouraged to use a notebook with carbon copies, since you may be required to turn in copies of your notebook pages);

(ii) Record procedures and observations neatly in ink, **as you do the experiment** (in certain cases, you may be allowed to include calculations in pencil). Any mistakes should be crossed out with a single line. Do not record your notes on scraps of paper and later record them in your notebook.

Some faculty use a columnar method to integrate Pre-Laboratory and In-Laboratory notebook entries. For the experimental part, each page is divided roughly in half into two columns; prelab entries are made in the left-hand column and then, as the work proceeds in the lab, a record is made in the right-hand column where it relates to the pre-lab outline. This provides a nice way to compare and contrast the suggested procedure with what you **actually** did.

(iii) Have consecutively numbered pages;

(iv) Include a Table of Contents at the beginning of the notebook (make sure you reserve a few pages for this) that has:

Experiment Title	Pages	Date(s) performed

Each time you make a new entry, update the Table of Contents.

V.B Pre-Laboratory Notebook Entries.

Each experiment should begin on a new notebook page and have an experiment title. You should prepare a brief narrative that at least outlines the purpose of the experiment, and summarizes the recommended procedures and required equipment. For instance, if you are carrying out the synthesis of a compound, the equation(s) for each reaction(s) should be given and include the chemical structure and name of each reagent.

Below each structure, give the physical constants (molecular weight, density, melting/boiling points) for each reagent. Over the arrow, indicate the reaction conditions (temperature, solvent) you intend to use. Indicate the structure of the expected product and theoretical yield. When appropriate, include a table of physical constants for ancillary chemicals such as solvents, extracting liquids, drying agents, and acids or bases used for subsequent neutralizations. If solutions need to be made, be sure you do the required calculations so you know reagent masses and solution volumes that will be needed. If pre-lab questions are assigned, answers should be included in this section.

V.C In-Lab Notebook Entries.

In the laboratory, you must record, in a step-by-step fashion, what you actually do. If the procedure is followed exactly as indicated in your pre-lab work, simply state e.g. “steps (1) – (5) were carried out as described on the previous page.” Recognize that while this is appropriate for only the very simplest steps, there are a variety of possible ways to accomplish even these relatively simple steps, and these differences in method could affect the overall outcome of the experiment. Thus it is essential to describe exactly what you did when there might be multiple methods for accomplishing even these ‘apparently’ simple steps. An uncomplicated example is: “NaI was added to the sulfuric acid solution with the aid of a glass funnel and the solution was stirred to homogeneity with a glass rod.” It might seem that too much detail is being given, but the use of a metal spatula to add the salt and to stir the solution might have resulted in corrosion, thereby introducing foreign metal ions from the spatula into the solution that might alter the outcome of your experiment. You would only discover this phenomenon in reviewing several repetitions where the addition and stirring was done by different means that had been duly noted. Of course, if you’ve modified any of the procedures, equipment, or materials, indicate the changes you have made: “the experiment was carried out as indicated in steps (1) – (5) on the previous page, with the following modifications … “

Indicate the source, purity, and, if available, lot number of all reagents used. Occasionally, you will encounter a bad reagent lot; this can often be used to trouble-shoot unexpected results. All raw data (weights, instrument readings, etc.) should be recorded with **the proper number of significant figures and associated errors. Units must be included on each entry**. Record all observations (temperature changes, color changes, spills/accidents) in your notebook. For each data entry and observation, be sure to indicate where in the procedure the measurement/observation was made. Also, especially in synthetic procedures, it is useful to track time in your notebook. This can be done by recording the time anytime you make a significant entry. Not every entry has to be timed, but making frequent note does help. When the procedure calls for you to do something for a set period of time, do not note that ‘the procedure was done as earlier described.’ If the procedure says to heat to reflux and reflux for ca. ½ hour, what is expected is that you will note:

“2:23 placed flask on hotplate to begin heating
2:37 reflux initiated
3:15 removed from hot plate, allowed to cool to RT”

Six months later when you review what happened in this experiment and you discover that you improved on the published yield by 20%, you may note that you refluxed for longer than the ½ hour initially prescribed, and this may induce you to initiate an investigation of whether you can improve the yields even more with a longer reflux.

You will frequently be asked to carry out intermediate calculations and/or to graph your data prior to leaving the laboratory. These calculations/graphs should be included in a "Data Analysis" section in the laboratory notebook. More sophisticated analyses will be conducted outside of the lab and potentially be included in the laboratory report. The instructor may also request a discussion of the experiment and conclusions.

The true test of the adequacy of your laboratory notebook will come from your peers. To assess whether or not you have adequately prepared your notebook entry, give it to one of your friends who is familiar with scientific procedures, but has not carried out that particular experiment. If he/she cannot follow and envision what you actually did, you have not noted enough detail.

VI. GUIDELINES FOR PREPARING TABLES AND GRAPHS

VI.A Rules for Table Preparation.

(1) Each table should be assigned a Table number and include brief title that is descriptive enough to tell the reader what you are showing in the table.

(2) A table should have at least two columns. If it does not summarize a critical amount of related information, the results can be presented in the document text. Each column should be labeled with a heading describing what the column represents, and units for numeric quantities. Never head a column with just units.

(3) Be sure to refer to every table that is included in the report within the text.

VI.B Rules for Graphical Presentation.

Note that there are a number of computer programs available for preparing graphs and fitting your data to linear and non-linear models. One of the most common ones (e.g. Microsoft Excel) is available for use on all personal computers on campus.

(1) A graph is a way of showing how a *measured* dependent variable (quantity plotted on the y-axis) changes with a *parameter you control* in the lab (independent variable plotted on the x-axis).

(2) Experimental data values should be *plotted as points* and the fit to a particular model/equation (e.g. the best straight line) should be *superimposed as line or smooth curve*.

(3) The x and y axes must be labeled with the parameter they represent, along with the proper units.

(4) Each graph should be indicated in your report as a separate Figure and given a Figure number that is referred to where you "introduce" the graph in the text.

(5) Each graph should have a brief figure caption that describes to the reader what you are showing in the graph.

(6) Error bars should be included on all graphs when appropriate.

VI.C FAQ's on Significant Figures and Error Analysis.

(1) When do I report error on a measurement of calculation?

Everywhere! Every number you measure in the laboratory and every calculation you do with these numbers will have error associated with it. Both *systematic* (e.g. a calibration error or failure to "zero" an instrument) and *random* (errors arising from intrinsic limitations of a measuring device, including the human eye) errors must be considered. Random errors are treated statistically by repeating the measurement and calculating a standard deviation or confidence limit.

(2) How do I propagate error?

Any time you perform add, subtract, multiply, or divide two numbers that have random error associated with them, you must use the error propagation rules. In addition and subtraction, error propagation involves summing the ***squares of the individual errors***; in multiplication and division, the process involves summing the ***squares of the fractional errors***. In both cases, the final step involves taking the square root of the sum to obtain the resultant error (addition and subtraction) or fractional error (multiplication and division).

RULES FOR PROGATING **RANDOM** ERRORS:

Any time you perform an algebraic operation on two numbers that have error associated with them (e.g. two measurements that you make in the lab), you must propagate the error according to the following rules:

(1) When you add or subtract two or more numbers (e.g. x, y, and z as the measured values that contain error)

$F = ax \pm by \pm cz$ (a, b, and c are constants)

the error in the answer is given by summing the **magnitude of the errors**:

$$\Delta^2(F) = a^2\Delta^2(x) + b^2\Delta^2(y) + c^2\Delta^2(z)$$

(2) When you multiply or divide two or more numbers (e.g. x, y, and z are the measured values that contain error)

F = axyz or axy/z or ax/yz (NOTE: a is a constant)

the error in the answer is given by summing the **percent errors**:

$$\frac{\Delta^2(F)}{F^2} = \frac{\Delta^2(x)}{x^2} + \frac{\Delta^2(y)}{y^2} + \frac{\Delta^2(z)}{z^2}$$

(3) For exponentials (base e or base 10)

$F = ae^x$

the error in the answer is given as:

$$\Delta^2(F) = a^2 e^{2x} \Delta^2(x)$$

(4) For logarithms (ln or log)

F = a ln(x)

the error in the answer is given as:

$$\Delta^2(F) = \frac{a^2}{x^2} \Delta^2(x)$$

(3) How do I report numbers with the proper number of significant figures?

When doing calculations with numbers, you should carry 1 or 2 extra significant figures through the calculation. When you are finished with the calculation, you should report the limiting number of significant figures. The error on the number cannot be any more precise than the number itself.

Example: If you measure a temperature of 37.5^o C, it is useless to say that the temperature has an error of 0.00566^o C (this is commonly done, since the number has three significant figures).

Tip: To make sure you report numbers and their associated errors properly (1) write the numeric result and error in scientific notation; (ii) use 1 number to the left of the decimal place; and (iii) make sure that the number of digits to the right of the decimal place is the same.

Example: Your final result (with the proper number of sig. figs.) is 1034 and the result from your error propagation gives you an error of 5.5. Change these numbers to (1.034 +/- 0.006) x 10^3 and report your answer as (1.03 +/- 0.01) x 10^3.

NOTE: If the error is larger than the precision of the result, do not report your result and error with greater precision than the result.

Example: Your final result (with the proper number of significant figures) is 1034 and the result from your error propagation gives an error of 100.5. Changing these numbers to scientific notation as described above gives a value of (1.034 +/- 0.101). However, since the error of 0.1 is larger than the precision of the result (1.034), you should report your answer as 1.0 +/- 0.1.

VII. GUIDELINES FOR FULL LABORATORY REPORTS

When you are first confronted with the task of preparing a laboratory report, it is important to recognize that this is an independent creative work. As the author of the report, you must strive to prepare your results in an organized, coherent, and technically correct fashion. It is not acceptable to simply assemble your results and submit the package to your instructor. You must provide the textual framework to present and discuss them in a clear and organized manner. By developing your report writing skills in laboratory courses, you will find tackling independent research reports and scientific articles much less daunting.

When writing a laboratory report, the first thing you MUST realize is that you cannot simply sit down and write. You must organize your results and decide how to present them before writing anything. It is useful to distinguish between the following kinds of data that will be included in your report:

(1) *Raw data:* The measurements that were actually taken in the lab (e.g. weights from a balance, temperature from a thermometer, volumes used, instrument read-outs). These data are recorded in your notebook during the laboratory and are used in subsequent analyses.

(2) *Intermediate calculations/data:* Any operation that is performed using your raw data (e.g. algebraic manipulation or slopes and intercepts from graphical analysis) will yield a set of intermediate data. You should tabulate these data, after performing the proper error analysis and error propagation.

(3) *Final results:* After “processing” your data through the intermediate calculations, you will obtain a set of final results. Typically, your final results represent the purpose of the experiment that you conducted and the quantities you set out to determine. Final results MUST be presented in an organized (e.g., Table, Figure , ,etc.) fashion, contain the proper number of significant figures, and have associated errors that came from the measurement errors and were propagated through the analysis.

VII.A Step-by-step Guide for Writing a Laboratory Report

(1) Review your laboratory notes and make sure you have all of the necessary measurements and descriptions of the apparatus and reagents used in the experiment. If you do not, consult your lab partner or instructor/TA.

(2) DO NOT simply sit down and expect to start writing. This is the hard way to proceed. Instead, take the time to organize your data and prepare all necessary figures and tables. THEN, you can simply discuss these figures when you are writing your report.

(i) Organize/tabulate your raw data (e.g. masses used, measurements made). For each table that you include in your report, assign a Table number and make sure you refer to the table in your text.

(ii) Perform the required intermediate calculations and graphical analysis and tabulate the intermediate results. For each graph that you will include in your report, assign a Figure number and prepare a BRIEF caption. In some cases, it will be appropriate to include experimental details such as concentration, solvent, temperature pertinent to the result. The caption should be descriptive enough to tell the reader what you are showing in the figure.

(iii) Obtain and tabulate your final results. Assign a running number to each table and provide a caption as described in (ii). Error bars should be included on all graphs when appropriate and a description in the text of what these error bars represent should be provided (i.e., standard deviation, 95% confidence limit, etc.)

(3) Prepare a DETAILED outline of your report that lays out the sections and sub-sections you wish to include. Indicate which figure or table will go in which section. In some cases, the important figures and tables that are created can be used to guide the various sections of the document. Within each section, prepare sub-sections that concisely represent and support the main subject. By doing this, you will minimize redundancy and maximize organization of your text.

(4) Now the easy part … write the Results and Discussion sections of your report. In presenting your data, calculations, and final results, simply use the figures and tables you prepared in step (2) as the basis on which to write. It is important to separate the facts from the interpretation. The facts are based on the measurements and observations you made in the laboratory and include some intermediate calculations. In some writing styles "just the facts" are included in a section known as the Results section of your report/paper. The interpretation drawn from these results (e.g., by applying a certain model to the analysis of your data) and justification for this interpretation in such documents is often provided in a Discussion section. An alternative to this style that is commonly used combines the results (i.e., facts) and discussion (i.e., interpretation) into a single cohesive section (i.e., Results/Discussion) so that when describing the facts, the importance of this

information can be discussed immediately, providing a coherent integration of what knowledge the reader should gain from this study. In either case, it is important to recognize which writing style is appropriate for the audience being written to with your document.

(5) Finish by writing the Introduction, Experimental, and Conclusions sections of your report. Be sure you've included all references, in the appropriate format, and other supporting information/appendices that are requested by your instructor. In writing each section, begin with an outline of the main points and sub-points you wish to include.

VI.B TIPS FOR WRITING YOUR LABORATORY REPORT

(I) Strive for clarity. To do this, you MUST keep the following in mind:

(a) Your text must direct the reader <u>smoothly</u> from (i) experimental data (either tabulated or in the report) to (ii) graphical or calculated quantities to (iii) tabulated intermediate or final results.

(b) Every equation, graph or table must be assigned a number and be introduced and discussed in the text.

(c) Your treatment of data must be sequential.

(d) You should insert a Figure or Table immediately after where you <u>first</u> mention it.

(e) The reader should not have to flip pages to search for results or calculations.

(2) Unless instructed otherwise, it is recommended that you write in the "third person." (e.g. Never use "I" or "we")

(3) Prepare the required Figures and Tables first, then generate your text to elaborate on them.

(4) Present the <u>facts only</u> as your raw and intermediate results (e.g. your tabulated results from your experiment and graphical presentation).

(5) Prepare organized, concise tables of your intermediate results (see definition above). All numeric entries must be included with proper significant figures, associated errors (either from direct measurement or error propagation) and units.

(6) To discuss your final results, you will take your intermediate results. Intermediate results may range from slopes, intercepts, etc. used to calculate physical quantities to description and characterization of intermediate compounds or materials. This is very much discipline-dependent; follow the advice of your instructor. Equations, figures, and schemes that you use for analyzing your results should be included in the text, numbered and discussed. Your text must guide the reader through the step-by-step logic of your

argument. In this section of your report, you will compare your results to literature values. If your results deviate from “expected” or published values, discuss why this might be so.

(7) Avoid ambiguous statements like: "the error in value 'x' is large." Instead, use a logical argument to make your case: "As seen from the numbers listed in the first column of Table 1, the standard deviation in the slope of the data fit to eq. (1) is larger than that for eq. (2). Thus, it is concluded that ...." (or “This suggests that…”).

(8) Note that you never report an error as deviation from a published value. This assumes that the published value is necessarily right (it might not be!). The error in a reported value is derived from the analysis of your data (e.g. error in the slope or fit obtained from the regression along with error propagation).

(9) Review significant figures!

(10) Reserve your Appendix for Supporting Materials. These may include sample calculations, supporting tables of data, spectra, quantum chemical calculations, etc. Do not include large tables of data that you have plotted elsewhere (this is repetitive). Always refer to what you have included in your Appendix in an appropriate section of your report.

(11) Figures must have only a caption that includes the relevant information about what is being shown. Titles on Figures are inappropriate in most cases.

LAST BUT NOT LEAST, FOLLOW THE SIMPLE RULES FOR PROPER **PARAGRAPH STRUCTURE!**

VIII. GUIDELINES FOR WRITING A LITERATURE REVIEW

In certain 400/600 level Chemistry classes at UMBC, you will be asked to write a literature review. In some instances, you may be asked to read and discuss/report on published work. If this is the first time you’ve been faced with this task, you may not know where to begin. This portion of the Guide is meant to help you gather information (literature searching) and to assemble it into a coherent review.

There are several things to keep in mind as you are preparing to write a literature review. First of all, the purpose of the literature review is for you to learn about something of interest to you and understand how the fundamental concepts you have learned about in your classes are used to solve novel problems in science. Next, in writing the review, it is your job to educate your peers and instructor and coherently teach the subject matter to them. Finally, you should be critical in reading and reporting on the literature. It is possible that the interpretation put forth by the authors may be flawed or that there may be other interpretations that have not been considered. Any conclusions drawn in the literature must be based on the evidence (usually experimental results) that is presented. In critically reviewing the literature, you must make sure the results are sound (Has the experiment been done properly? Were key controls missed?). It is important to understand that, in most cases, the authors and co-authors on published papers are frequently research students like yourself. Next, you must learn to draw your own conclusions from the data. Don't necessarily believe the conclusions drawn by the authors, since there can always be alternative explanations.

VIII.A General Considerations for a Literature Review.

In choosing a topic for a literature review, you may be given some guidelines by your professor (e.g. what journals you should draw from; what sub-topics you should focus on). In all cases, you should clearly understand what key problem the authors are addressing. You should understand this problem, why it is important, and what key questions will be answered or what technology will be advanced. In all cases, the authors should make it clear why their approach is different than what has already been published. This is the "sales pitch" part of the literature you are reviewing and must be conveyed in your report.

Next, you should understand the experimental or theoretical approach taken by the authors. Is the method they chose to use appropriate to solve the problem, or is there a better approach? In many cases, you will be reviewing a group of papers that are addressing the same fundamental problem. In your review, you should be able to identify the differences that exist in the different approaches and compare and contrast the approaches.

VIII.B Choosing a Topic: Literature Searching Resources at UMBC.

Please see UMBC's Library web site for Chemistry and Biochemistry specific literature searching resources:

http://aok.lib.umbc.edu/subjectguides/CHEM-SG.php

However, realize, that a single search engine generally will not provide an exhaustive list of the pertinent literature and that multiple searches with various related key words will be required. Often times many of the words that you will need to use for literature searches will be unfamiliar to you when you begin this review process (as different scientific field often use different terminology for the same topic), so it is important to perform additional searches later as you begin to learn alternative terminology for the same topic. This will result in the optimal search for previous literature. With a growing number of journals available in **full electronic format**, retrieving this work is becoming easier in many cases, however, you are still responsible for also retrieving articles from non-electronic formats as well, including those not stored in the campus library. In such cases, inter-library loan or other alternative means of acquisition should be employed.

Unless otherwise instructed, your literature review should be based on the *primary literature*. Primary publications represent those in which information, experimental or theoretical data, and ideas are first presented, in written form, to the scientific community. ***You must read the primary publication to cite it as a reference!*** Once this information is published and publicly available, it may be cited in *secondary publications*, such as review articles. Review articles are generally quite useful in that they review and compile data from the primary literature. If you can find a review article on a topic of interest, use it as a starting point. However, your main document should be written after reading the primary references that are cited within the reviews.

VIII.C. Writing the Literature Review.

After choosing a topic and gathering your references, you are now ready to sit down and organize your literature review. Before you begin writing your literature review, it is useful to look at examples of the secondary literature. Examples of the secondary literature include Chemical Reviews and Accounts of Chemical Research. Articles published in the latter journal are oriented towards the non-specialist audience and may serve as more suitable examples for your own written literature review. In addition, review articles are often published in special issues of many journals specific to a certain field of research.

The specific format of your literature review may vary from assignment-to-assignment, but all literature reviews should include the following key sections:

(1) *Introduction:* The introduction should define the problem that the research addresses. Identify the hypothesis: a statement implicitly written or implied in the paper that the authors wish to prove or disprove. The introduction should clearly frame the work in the context of the chemical and biochemical sciences. The significance and novelty of the published work should be summarized. Finally, the Introduction should be a preview for the reader of what research will be reviewed. This is especially important if literature from more than one research group is being presented.

(2) *The Review:* This is the main section of the document. You should begin by presenting and briefly describing the approach that the researchers used. The approach should not be given in as much detail as in the paper. However, you should provide enough detail so that your audience and peers can envision what was done and what facilities were used. The review should assemble and organize the key results from the literature being reviewed into a cohesive and flowing story. Gather related results/tables and copy/paste these into your review at the appropriate location (with proper citation). Be sure that you cite the source of the figures and tables that you include in your review. You should also note that if your review is to be published, you will need permission to reproduce the figures and tables. In the body of your text, present these results (in a similar fashion as you would your own if you were writing a scientific paper). In doing so, you should keep in mind that you are presenting the results as evidence to support the story in your document. As such, be sure the presentation is clear, logical, and cohesive (just as if you were teaching the material). After presenting the relevant results, offer an interpretation of the data: “From the results shown in Figure 5, the authors concluded that ….” If you are comparing the research from multiple laboratories, you should present related result sets and compare/contrast the differences.

This part of the literature review should contain a *critique.* In this section of your review, you should discuss the authors’ interpretation of the results and compare/contrast the results from the different papers you have included. Summarize the strengths of the articles and approaches that you have presented. The most important aspect of the critique is to assess whether or not the authors' interpretations are justified by the data (the facts). It is extremely common for authors to over-interpret their data and to make claims that are not justified. Do not believe these claims unless you can justify them by looking at the data. Specific questions to keep in mind:

(i) Have the authors' interpreted the data properly? Look at the data closely as if it were your own and draw your own conclusions.

(ii) Did they miss key controls?

(iii) Are there alternative interpretations that the authors have overlooked?

(iv) Was the scientific approach that was used appropriate for the question being addressed?

(v) What are the strengths/weaknesses of the literature you've reviewed?

You should critically read/review published work just as you would your own. Consider the facts; look closely at the data; then reach a conclusion.

(3) *Summary/Conclusion.* This section should provide a summarized overview of what was included in your review. Reiterate the key points, the conclusions that are solid, and those that are still under debate. In other words, at the end of the review, where are the researchers at? Did they answer the questions they set out to? Did they find surprises? Have they advanced the field? Discuss/propose what could be done for future work to address any ambiguities and advance the field.

THROUGHOUT THE DOCUMENT, PAY STRICT ATTENTION TO RULES FOR PROPER PARAGRAPH CONSTRUCTION!

IX. GUIDELINES FOR WRITING A RESEARCH REPORT

IX.A Doing the Research.

During your junior/senior years (and beyond … perhaps even before) you may become involved in a research project with a faculty member at UMBC or with an off-campus internship. If you are considering graduate or medical school, you should seek every opportunity to get involved in research. To identify a faculty mentor, check out the departmental web site to see what area of research you may be interested in and available research opportunities. It is useful to become involved in organizations such as the *Chemistry and Biochemistry Council of Majors (CBCOM)*, where you will have an opportunity to meet faculty and learn about their research. Then talk to the faculty (don't be afraid of knocking on doors!) and use your TAs as a resource to find out what research they are involved in.

Working in a research lab is very different than classroom laboratories. In undertaking a research problem (or a sub-project that is part of a bigger program), you should keep the steps of the scientific method in mind:

(1) Identify a problem (based on what's published and the questions that remain).

(2) Develop a hypothesis.

(3) Develop a procedure/method to address the hypothesis: What would be observed if the hypothesis is true? What does the hypothesis predict? How can it be tested? It is most important to bear in mind that the best experiments are those that can "falsify" or disqualify your hypothesis. These types of experiments require rethinking of assumptions and alterations of fundamental relationships that ultimately are manifest in new hypotheses and scientific advance.

(4) Collect and analyze the data.

(5) Derive a conclusion. It is important to remember that you never prove a hypothesis. Your results and conclusions are consistent or inconsistent with your hypothesis, but a hypothesis is never proven (alternative explanations, equally consistent with the data, may arise).

As you enter the research lab, it is important to pay particular attention to Section V of this Guide. As an independent researcher, it is critical that you keep a complete and accurate notebook of what you actually did and where supporting files (e.g. computer files containing spectra and data) are stored. This is the only record of what you did and will be a required resource in publishing and documenting your science. Keep careful notes and regularly back up your data files (hard drives crash and other data storage methods get corrupted!).

IX.B Writing the Research Report.

When you've finished your study (as defined by the scientific method), you are now ready to write your research report. The following format of your research report is recommended for your end-of-project paper in CHEM 399 or 499. It is also the format you should use when writing a scientific manuscript that you will submit for publication in an appropriate journal. Please be sure to review the guidelines for paragraph construction and table/graph preparation. The rules of scientific writing don't change!

The format set forth by the American Chemical Society's Committee on Professional Training represents a good initial guideline to follow when preparing your research report. However, you should check with your research advisor before writing to ensure the desired style. These guidelines can also be accessed through the following link:

http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education/cpt/ts_rrguide.html

X. Scientific Ethics and Academic Integrity.

In science, you will rarely make breakthroughs or solve problems as an individual. When you are identifying a problem and designing the methods to solve it, published works of others are usually consulted. When analyzing and interpreting your results, you will frequently use models that have been published and applied in similar studies. The "conversation" that develops, either through formal publications, conference presentations, or informal discussions are crucial to doing your research or completing an academic exercise. As such, you must understand the ethics of this open communication.

Plagiarism occurs if you do not cite the source of information or ideas. You must give credit (through a properly formatted citation) when you (i) use another person's ideas, opinions, or theories; (ii) quote any fact or statistic that is not common knowledge (i.e. "the sky is blue"); (iii) directly quote the written or spoken words of another or (iv) paraphrase another person's words or ideas. In general, you should avoid directly quoting words of others, unless the style of the quote (as opposed to the idea it is conveying) is crucial to your purpose. Do not overuse quotes; a report should not be dominated by them.

Many of the laboratory and lecture courses that you take will include group activities. For example, it is common to work with a laboratory partner to conduct and analyze the results of an experiment. While group discussions are encouraged to help you understand and grasp the science, your final written work must be your own creation. **A submission of written work that contains identical content (sentences, tables, or figures) as that of a classmate's will be treated by the faculty member as academic misconduct.**

Students should consult UMBC's Academic Integrity web site for further details and policies at UMBC: http://www.umbc.edu/integrity/. A "Statement of Values for Student Academic Integrity at UMBC" can be found at

http://www.umbc.edu/provost/integrity/Honorcode.htm

XI.A Bibliography and Electronic Resources.

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

Strunk, William Jr.; White, E. B.; Angell, Roger*The Elements of Style*, Longman: New York, N.Y., 2000.

Also available on-line: http://www.bartleby.com/141/

Day, Robert A. *How to Write and Publish a Scientific Paper*; Oryx Press: Phoenix, AZ, 1998.

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

Beall, Herbert; Trimbur, John A *Short Guide to Writing About Chemistry*, Addison Wesley Longman: New York, 2001.

Williams, Joseph, M.; Booth, Gregory G. *The Craft of Argument: Concise Edition*, Addison Wesley Longman: New York, 2003.

Schoenfeld, Robert. *The Chemist's English,* 3rd ed.; VCH: Weinheim, Germany, 1990.

Kramer, M. G.; Leggett, G. H.; Mead, C. D. *The Prentice Hall Handbook for Writers*, Prentice Hall: New Jersey, 1995.

The American Chemical Society (http://www.acs.org) and other suitable scientific organizations have excellent collections of on-line resources (with free-of-charge links) for writing in science. To access the list from the ACS, click on http://www.acs.org. Follow the links for Professionals, ACS Library (bottom of page under "Other Resources"), Library and Information Center (under Searching the Chemical Literature) to Scientific writing Resources (under Research tools). The specific URL:
http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=library%5Csciwriting.html

Some of these links include:

A Handbook for Technical Writers and Editors, published by NASA, is another useful guide to scientific writing and editing. The entire document is 108 pages long (464 kB) and can be downloaded as a PDF file (http://stipo.larc.nasa.gov/sp7084/index.html)

MedBioWorld. Contains 25,000 links and is claimed to be the largest medical reference site, including all medical journals and medical associations, and similar resources in the biological sciences. Links include 6,000 medical journals in 80 subspecialties, and the home pages of 4,000 medical associations. Other research tools include medical glossaries, disease databases, clinical trials and guidelines, and medical journals offering full-text articles. (Numerous links to writing and style guides can be found through the "writing and presenting scientific work" link. Links include dictionaries, accepted abbreviations, style guides and guides to writing assistance). http://www.medbioworld.com/advice/presenting.html

XI.B Laboratory Practices and Safety.

MSDS (Material Safety Data Sheets) Directory: http://www.ilpi.com/msds/index.html

National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards and International Chemical Safety Cards: http://www.cdc.gov/niosh/npg/npg.html

Safety reference books/directory: http://www.lib.uchicago.edu/e/su/chem/safety1.html

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