LABORATORY NOTEBOOKS AND POST-LAB ASSIGNMENTS

Laboratory Research Notebook

Proper academic and industrial lab practices require that all work in labs be done directly from a lab research notebook. These documents, while not published like journal articles, are the backbone of scientific inquiry and discovery, and they must contain the complete and unaltered record of the work that is done in the lab. A lab research notebook will contain the complete record of the experiments that were performed, including the procedures, reagents, and data. These records are then used to pass on information to the next researchers on a project, serve as legal documentation for proving intellectual property (when applying for patents), eliminate concerns over potential fraud, and are a legacy for the research group.

Long after a particular researcher has moved on from the research group, the lab notebook will remain as a crucial reference source for future work. While it is doubtful that the work done in undergraduate lab courses will be needed for future reference, the skills of keeping these notebooks will be useful as you venture forth into research positions, including undergraduate research. As such, it is crucial that you begin to develop proper habits for documenting your work in lab research notebooks.

To begin developing these skills, all lab work for this course will be done in a research notebook, and the duplicate pages will be submitted to your instructor before leaving the lab so that they can provide feedback, guidance, and direction. Moreover, since all of your work will be done from pre-prepared notebooks, use of this lab manual will not be permitted in class during the experiment; that said, you should still bring your manual with you so that you can refer to it during the analysis time at the end of labs.

Preparing research notebooks ahead of work in the lab

Proper preparation of your research notebook is the best way to make sure that you will be ready to do your experiment with confidence and fidelity to your planned protocol. A substantial portion of the notebook pages needs to be completed before arriving at the lab so that you are prepared and organized in your work. Details needed before lab include:

- The title of experiment, your name, the date, and your lab section. These details need to appear on all pages, not just the first page.
- An objective statement. This can either be a bulleted list of the in-lab outcomes and goals, or a *very brief* paragraph describing the outcomes. A bulleted list is typically more useful and will enable you to check your progress as you go. These objectives should include the specific experimental outcomes that you hope to achieve.

- A detailed procedure. Most often you will be following a procedure that has been provided to you. In this case there is no need for you to copy the procedure verbatim; rather, make sure that the procedure you write is detailed enough for you to follow and includes all of the pertinent details that are necessary. Add extra details where you think you might need them, and omit others that you find to be overly verbose. Make sure to diagram any apparatus that will be used, if applicable. For multiple dilutions it will help to diagram or sketch these dilutions (to make sure that they are clear).
- Safety information and potential hazards. Labs can be a dangerous place, and knowing about the potential hazards in advance is the best way to avoid potentially-harmful situations. Any and all chemical, or physical, hazards related to the experiment must be listed and explained **inside the procedure**. Consider making 'warning' boxes in your procedure.
- Waste handling instructions. A detailed description of how all the waste components will be handled. This must be include inside your procedure write-up, not at the end.
- Data tables. Tables, placed next to the procedural steps that are relevant to the data collection, for the values that you expect to collect/measure must be prepared **in advance** of the lab session. This is the best way to make sure that you will have all of the information that you need once you leave the lab. In the fast-paced, sometimes nerve-wracking, laboratory setting it is easy to miss important details; having tables set up in-advance allows you to see, at a quick glance, what exactly you'll need to record.
- Observations. While these observations will be made during the performance of the experiment, make sure to leave ample room for you to document what you observe as your do the experiment.

Examining a sample notebook entry

The sample notebook entry in Figure 1 highlights a few important things to keep in mind when preparing your lab notebook. Specifically:

- All of the important information at the top has been filled-in, on all pages, *before* lab.
- Objectives are listed in a concise way that allows the student to easily identify objectives left to complete.
- Appropriate room for observations is left next to the procedure, and the observations made in lab are detailed enough to be understandable. Some students prepare their notebook pages in one color pen (black ink, for instance) and make observations and record data in another (red or blue ink) – this can be very helpful for working with your notes.
- Tables are prepared, before coming to lab, for all of the data that will need to be recorded.
- Waste and safety concerns are listed inside the procedure.

It is also important to note that procedure is written in a way that the student can easily follow – a lot of details when necessary and fewer details when appropriate. Notice the two versions of step #5; it is likely that the first version might show up early on in the year, whereas the second version would be used as the student develops more comfort and confidence.

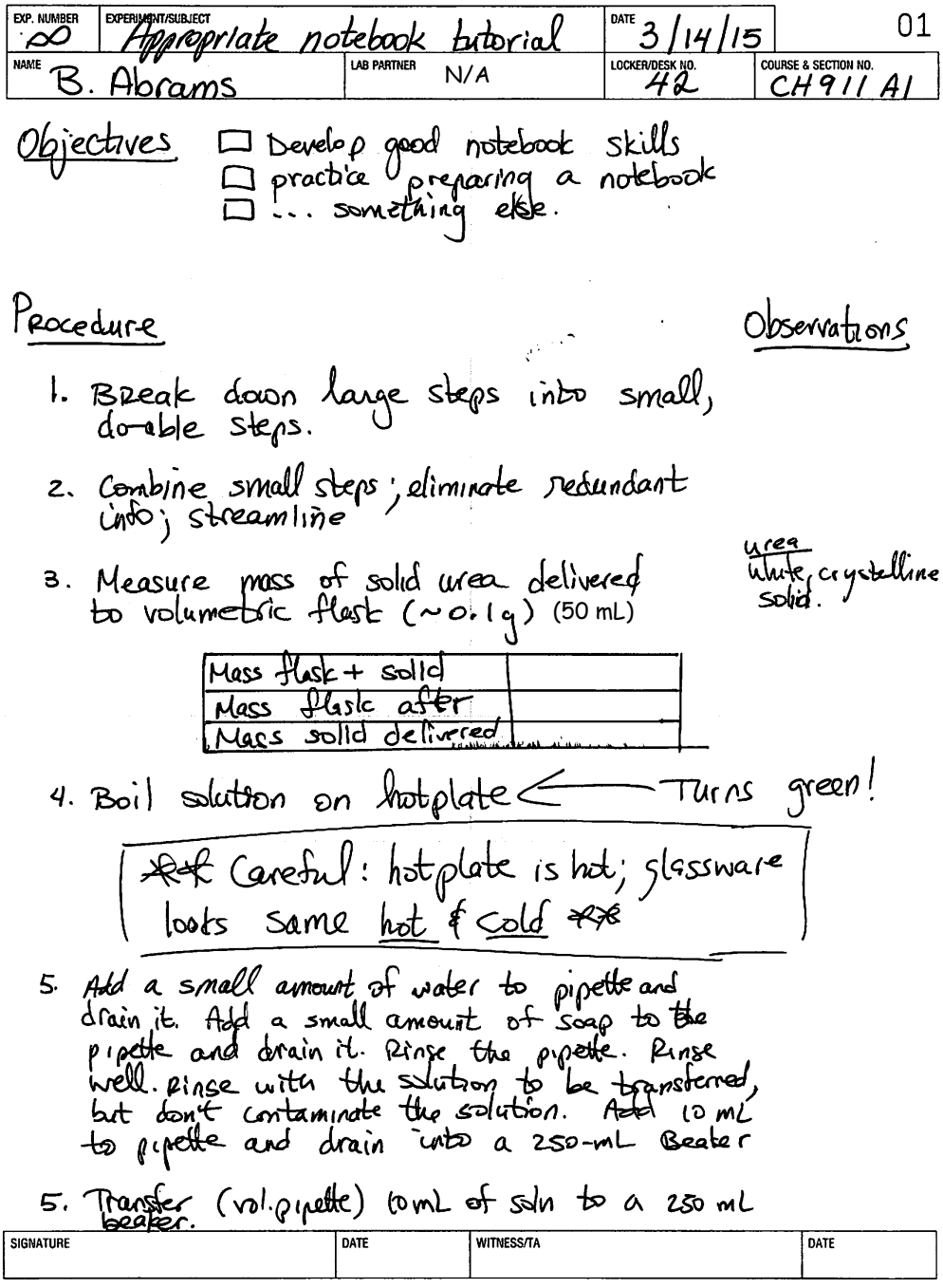

Figure 1: Sample notebook entry that highlights important aspects to a successful research notebook.

Working with research notebooks in the lab

In the lab, all work must be done directly from and in the lab notebook – this includes recording all data, including seemingly insignificant information and observations. For professionals, this is to ensure the strongest levels of integrity. For students, this is good training for future research positions, and limited reliance on memory. The following items are added to your research notebook during the experiment:

- Name(s) of any co-investigators that are actively working with you on a protocol (lab partners) or supervisor (if applicable).

- Observations. A researcher needs to take detailed notes and write their observations during an experiment – both planned and unplanned information. Actual times, colors and color changes, temperatures, and deviations from the written procedure are some of the observations that you should be making in the lab. These are immeasurably helpful for people who will want to reproduce your work and for yourself. Needless to say, all data must be recorded in the notebook.

- Data. All data must be recorded **directly into the notebook** using the tables that were constructed before the lab. This includes masses, volumes, and other exact measurements that are recorded in the lab. Data or spectra recorded on instruments should be mentioned in the notebook pages and a note about where it is stored. Always keep an unedited copy of all data files, and work from the copy.

- Calculations. It is sometimes helpful, though not always necessary, to perform some preliminary calculations in your notebook. Include interpretations of those data, when applicable.

- Instruments. It is important to note pertinent details about instruments used in an experiment when the choice of instrument has a potential impact on the experiment. Glassware (burettes, pipettes, etc.) is rarely included in this category. Conversely, things like spectrophotometers, pH meters, thermometers, centrifuges, and cell culture tables should all be well-documented – including make, model, and settings used.

General notebook practices and guidelines

- Entries must be written in pen, not pencil. Never use error correction fluid or pens.

- When you make errors, simply draw a line through the incorrect entry and enter the correct information. Do not scribble. Write your initials next to the correction and include the data the correction was made. It is also useful to provide a reason for the correction, if applicable.

- Never remove a page from a research notebook (except for the duplicate copies that are submitted in lab courses), and never skip pages. If you accidentally skip a page, or make a large mistake, cross out the page and provide an explanation.

- The entries should be legible, and information should be organized and clearly labeled.

- Use lots of space. Lab notebook should be geared toward functionality and legibility, not saving space.
- Make a note in your observations about any data that is recorded on external instruments. Include a description of what is recorded, where it is saved, and the filename.
- Always include the make and model of analytical instrumentation (spectrometers, pH meters, etc. – pretty much anything that uses electricity). Also, make sure to document the specific instrument parameters that are used in your experiment (calibrations, sampling frequency, etc.).
- Students will submit the duplicate pages of their research notebooks before leaving the lab. You should submit the copies (not the originals), as you will want the originals – which are easier to read – to work from after the lab.

Post-lab Assignments

After completing an experiment, you will be expected to complete and submit a post-lab assignment. These assignments will typically be comprised of your data analysis and a series of conceptual questions related to the lab. On occasion, you will also be asked to write a scholarly paper related to the experiment. **Important note:** scholarly papers are only required for certain experiments. The details about each experiment's post-lab assignment are found after the procedure.

The post-lab assignment that you submit must constitute your own intellectual property and effort. In other words: they are individual work only. That said, you are highly encouraged to discuss your work with your peers, get support and guidance from your instructors, and work in groups as you complete these assignments. Detailed guidelines concerning group work are provided in the previous part of the lab manual under *Professional Standards in Chemistry Labs*.

Submitting post-lab assignments

Typically, post-lab assignments will be submitted on Blackboard using TurnItIn, and are due two hours before the start of the next lab period. Your instructor will announce any changes in the due dates of these assignments, if applicable.

While TurnItIn will accept a few different file types for submission, it is important that you always submit your assignment as a PDF file – Word for PC and MAC can both produce PDF files from your documents. Submitting your assignment in another form (e.g., as a docx Microsoft Word file) will cause major (bad) structural changes to your paper. Submitting a PDF file, on the other hand, will make it so that the instructor will evaluate the paper as *you* intended them to see it.

Finally, all success TurnItIn submissions will result in a confirmation email being sent to your school email address a few minutes after the file is accepted. Always make sure that you've received your email confirmation that the assignment has been received. If you don't get a submission receipt within 30 minutes, submit your assignment again as it has not actually been received. It is your responsibility to ensure that your work is successfully submitted and received.

General guidelines for post-lab questions

Consider the following important guidelines for post-lab assignments:

- Answers to the post-lab questions must be typed. Typed equations need to include units and be formatted in an appropriate manner such that they are legible and straightforward for the instructor to read. This can be accomplished by using the equation editor in Microsoft Office or LaTeX. Refer to Lab #1 and Writing Chapter 2 for additional suggestions and guidelines about typesetting equations, and more. Make sure that the instructor will be able to follow your work without difficulty.
- The questions must appear in the correct order, including all exhibits (tables, figures). Note: "Questions for Thought" are not optional, thought-provoking questions; rather, they are questions to be answered after you've completed your analysis. Often, these questions will tie together different concepts and require some research.
- You do not need to copy the question text into your assignment – that is an unnecessary waste of your effort and time.
- For multiple trials of the same experiment, only one full set of calculations need be shown for each question. For replicate calculations, the results can be summarized using appropriate statistics and, when necessary or relevant, presented in a table or list. The following calculations never need to be shown: average/mean and standard deviation. In all cases, how the values were calculated must be stated explicitly.
- You are never required to show how average and standard deviation are computed manually – it is expected that you used Excel or a similar package to compute the average. All other calculations, however, need to included. For example: when computing a 95% confidence interval, make sure to explicitly include the expression for the confidence interval with the proper values of s, t, and N.
- A large portion of each lab is the data analysis that you will perform; it is crucial that your work be legible and organized. Instructors will not evaluate work that is not properly organized or prepared.

Successfully approaching your post-lab assignments

Consider the following general suggestions for success in preparing your post-lab assignments:

- Read the post-lab assignment questions *before* going to lab. Have in mind the questions that you will need to answer while you are doing the lab. Talk to your lab instructor and peers; they will likely be able to give you good insight into these concepts.
- While most of the experiments that you will perform do not take the full lab time, it is expected that students will remain in lab for the entire assigned time. During all remaining lab time, after the experiment is complete, students will begin working on their data analysis and post-lab assignments.
- Start working up your data as soon as possible. While you will begin the analysis in lab, it is unlikely that you will finish all of your post-lab assignment during the lab time. It

is highly advisable to set-aside time soon after the lab ends – either later that day or the next day – to complete the post-lab assignment. Previous students have confirmed that working on the post-lab assignments immediately after the lab substantially reduces the time that needs to be spent completing them. One of the reasons for this is that, as time passes, it is natural that you will start to forget exactly what you had done in the lab and, therefore, will end up spending a lot of time trying to remember what you did. Instead, it is most advisable to start working on the analysis immediately (within 24 hours), while the material is fresh.

- Working in groups, or at office hours, on the data analysis and questions for thought can be very helpful. Don't copy another student's work, but work together to decide what you need to do to analyze your data. **Never give** your work to anyone else, even if you worked together, or collaborate on documents. See detailed notes on academic integrity in the section on *Professional Standards*.

- Plan your research: what do you know? What don't you know? About which topics do you need more information in order to understand the outcomes of your experiment?

- Use previous assignments, and "Questions for Thought," to help guide you in your work. As the course proceeds, less information will be given and more thoughtfulness will be expected.

- Using Google to do research can be good when the thing you are looking for is rather straightforward: the molecular weight of a compound, the structure of a molecule, or other trivia that are commonly known and likely to be correct (thermodynamic data, common chemical reactions, etc.). Unfortunately, however, many websites – including those with `.edu` extensions (i.e., schools and faculty webpages) – contain information that is factually erroneous. Moreover, it can be *very difficult to discern* good information from things that are outright incorrect on the internet. Writing Chapter 6 contains detailed insight and guidance on locating and referencing useful information.

- When looking for information to supplement your understanding about the systems, techniques, and processes that we will study, make sure to search for and use good information from authoritative sources. Use peer-reviewed textbooks, reference manuals (such as the CRC Handbook of Chemistry and Physics), journal articles, and review articles, most of which can be easily accessed online. Use `scholar.google.com` to help refine web searches to include mostly scholarly sources. Finding good sources of information can be tough at first – come to office hours and speak with your instructor in lab to work on these skills.

- Asking questions is the best way to get insight and answers that you are seeking. Attending office hours and study groups will substantially improve your productivity and the quality of your work.

Scholarly Papers

Most experiments will **not** involve writing a scholarly paper based on your experiment, and your instructors will make sure to indicate when a scholarly paper is expected. The last part

of this lab manual is the *Undergraduate's Guide to Writing Chemistry Papers* – a detailed explanation of the nature of scholarly papers and guidance for how they are prepared effectively. While you may not need this entire guide for this course, previous students have found this to be an indispensable tool for future work in other courses and their research.

Consider the following important guidelines for post-lab assignments that involve writing scholarly papers:

- Scholarly papers will contain three sections: (a) paper, (b) references, and (c) supporting information.
- Papers and references must be typed (including equations) for all sections (including the supporting information, which contains the calculations, data analysis, and questions for thought). Typed equations need to include units and be formatted in an appropriate manner such that they are legible and straightforward for the grader to read. This can be accomplished by using the equation editor in Microsoft Office or LaTeX. See Lab #1 and Writing Chapter 2 for additional suggestions and guidelines about typesetting equations and more.
- The supporting information (data analysis and questions for thought) must be complete and in the appropriate order – all of the instructions for post-lab assignments (above) apply to these sections. Exhibits (tables, figures) that will be presented in the paper also appear in the appropriate place in the supporting information. Any "Questions for Thought" should also be answered at the end of your Supporting Information section. In general, these questions provide good insight into the types of things that could be discussed in the paper.
- A scholarly paper will always start on a new page. An appropriate title and the name(s) of the author(s) should appear at the beginning of the paper. References do not start on a new page; rather, they follow immediately after the conclusion of the paper, before the Supporting Information. The Supporting Information may have a separate references section at the end if you used references in preparation of the Supporting Information that were not necessarily included in the paper.