The Laboratory Notebook

The laboratory notebook is first and foremost a record of one's work in the lab. If that seems an obvious statement, consider the fact that many students INSIST on recording experimental observations and data on their hands, scraps of paper towel, toilet tissue, etc. Of course these items are never turned in, and therefore instructors assume that at one point or another this data was transcribed.

A good scientist LEARNS to "work" in a notebook just as surely as he or she learns to work in the lab.

While an expert at lab note-taking may produce a notebook that is a work of art, the ultimate aesthetic appeal of a notebook is far less important than its logical sequence and clarity as a record of investigation. "Wanting it to look neat" is therefore not an acceptable excuse for not entering all data and observations directly in the notebook. Neatness comes with thought and lack of haste in recording. "Think first, then write" should be a motto.

So what exactly goes into a lab notebook? The requirements vary from situation to situation, but *for this course* you are responsible for the guidelines given below:

1) at the top of the first page of an experiment: **the complete experiment title**
the date
your name

[*note that boxes are provided for each of these*]

2) at the top of EACH succeeding page: **your name (initials are OK)**
the experiment title (abbreviated intelligibly)

3) the body of the report:

Each experiment should begin with a *brief* statement of what is to be accomplished (the "purpose"). WHY ARE YOU DOING IT? WHAT ARE YOU TRYING TO FIND OUT? **Rarely is the purpose simply "to measure...." or "to determine.....".** Generally we are trying to find out something or make something and test its properties. That is the immediate goal out front but behind it lies an exploration of important principles. This initial statement should indicate that you are not just doing the experiment because it is next on the syllabus.

The next section might be called the "method" but it should be more than a list of steps you will follow to get out of the lab as quickly as possible [a "list" of any kind is generally to be avoided]. Just as a good essay requires a unifying theme and logical development, so this part of your report should indicate that you have some knowledge of the important principles underlying the work to be done, a plan for achieving the purpose and an understanding of how the observations or data will be used to that end.

The method can actually be divided into three parts (or even three paragraphs, for shorter methods) which parallel these ideas. First would come a brief discussion or background setting for the important principle(s) involved in the experiment. This would--at least--include the chemical principles but might also involve the first use of an instrumental technique. Be as brief but complete as possible. Try to distill the ideas down. If you don't understand the theory behind some of the steps, this is the time to look it up or ask the instructor.

Next explain how you intend to accomplish your task(s). Details such as "I will add 3 mL of HCl" are inappropriate. A statement such as "I will dissolve the metal sample in 12 M HCl", followed by a balanced equation, is entirely appropriate. **A "method" is NOT a procedure.** In the teaching laboratory the purpose of the student notebook is not the same as it is in industry or research. There is no expectation that another person could pick up your notebook and reproduce the entire experiment without any other information. That is not the point. **What is expected is that someone who knows something about chemistry would be able to follow the gist of what you did and understand the purpose behind what you did.**

This is an appropriate section for some preliminary literature references (e.g., "the free energy for.....is.....(CRC Handbook, 52nd ed., p.xxx) but no values are found for.....which will be determined by .....").

Finally you should indicate how the information you obtain in the lab will be used to achieve the purpose. This can take many forms. At the least imaginative end of the spectrum you can simply lay out the calculations to be done with the numerical data. A better use of the notebook page might involve describing the logical sequence of data processing from the raw numbers to the quantity sought. Descriptions of every change from grams to moles are inappropriate.

Your daily work will follow. Data should be recorded in neatly prepared and NUMBERED tables (keep a ruler handy). Numbering of the tables will facilitate discussion of results at the conclusion of the experiment. **Because many experiments extend over several days (or longer) it is important to get in the habit of dating entries in a table or on a page.** In general record any pertinent observations. Non-numerical information may be written in simple comment form. At the end of a working day, turn in all carbon pages *for that day* to the instructor. They will be returned to you on the following working day, possibly with notations. Remember, additional entries on a "used" page must be dated.

If you have intermediate calculations to do on your data before the next day's work, begin on a new page so that a carbon record is made. These may be turned in with the next day's pages (assuming there is more practical work to be done).

At the conclusion of an experiment, return all of the carbon pages to the instructor for grading. Computer-generated work (graphs, spreadsheets, etc.) should be attached at the end of the report and referenced in the body of the report. IT IS VERY IMPORTANT THAT SUCH WORK BE SUFFICIENTLY LABELED AND DESCRIBED, ESPECIALLY GRAPHS AND TABLES. Because the instructor may "mark up" your report, you should make two copies of all computer-generated material. The second copy will be attached to your original lab notebook pages to make a permanent record of your work. More about that later.

SOME GENERAL COMMENTS

1. use black ball-point ink
2. **do not decorate errors**; a single line through an entry will suffice---you may decide later it was right after all!
3. be sure to record PRIMITIVE data---for example, initial and final buret readings, not the difference done in your head
4. hand-drawn graphs should fill the entire page as nearly as possible; computer generated graphs should not be microscopic or misproportioned (i.e., graph fields should be nearly square).

The End

Assuming that you reach the end of an experiment, you will need to tie up all of the loose ends to make ONE END. You should begin by trying to show how your work addresses the goal you set out to accomplish. This can often be done neatly with a summary table comparing your calculated results with (referenced) literature values.

An error analysis of the type requested with the particular experiment is a MUST. Detecting error is generally simple since results will not agree with theory or handbook data. *Explaining* error is another matter. An acceptable error analysis is specific to your results and not general. Blaming instruments is NOT a legitimate recourse. Instead, you must go back through the experimental procedure and decide where an error could have been made that would result in the high/low or outrageous value. Then you must judge the likelihood of having made such an error and explain its impact on your results. Some experiments by their nature *cannot* yield accurate data. This is also a possible avenue for discussion but it must be backed up with theory.

Comments pertinent to your experience in the lab are fine. The style should be first person and relatively informal, but accurate. **Don't be verbose**, but try to discuss intelligently what you did and why it shows (or does not show) what you set out to show. If the experiment went wrong, what would you do differently if you had more time?

Summary

Above all, make the laboratory notebook a record of your learning experience in A.P. Chemistry. Your notebook will very likely end up "non-linear" as we work through the year, starting a new experiment before you finish the report on a previous one. *At the end of each semester you will be required to turn in a "linearized" version of your work.* This is accomplished by removing the original pages of your notebook and placing each experiment in order, regardless of page number. Computer-generated work for an experiment would follow it. All pages are placed in a binder **reserved for this purpose**.Very often Colleges and Universities will ask to see a record of your lab work if you request to "skip" Freshman Chemistry. Make it a good one.

What follows are two example "pre-labs" for the first experiment of the course. This is not an invitation to copy but rather an attempt to clarify some of the general comments on the preceding pages. Compare the "good" example with the "bad" example. Try to avoid the latter.

GOOD

DATE	EXP. NUMBER	EXPERIMENT	
9-4-02		The Law of Multiple Proportions	01
NAME		LAB PARTNER	LOCKER NUMBER
Earl N. Meyer			

Purpose: to determine the chemical formulas for compounds of copper with bromine and copper with oxygen, and use the data collected to illustrate the law of multiple proportions.

Method: The Law of Multiple Proportions states that in compounds composed of the same two elements, the mass ratio of the elements present in different proportions (as opposed to the fixed element) will be a small whole number. I can demonstrate this by determining the composition of two different compounds containing fixed amounts of copper but different amounts of bromine. The masses of bromine should be in a simple whole number ratio. The first compound will be given and the second formed by gradual decomposition of the sample to metallic copper.

The experimental sequence begins with a massed sample of copper bromide (1). I will treat the compound as outlined below, massing at each stage:

copper bromide (1) + heat $\rightarrow$ copper bromide (2) + bromine

copper bromide (2) + nitric acid + heat $\rightarrow$ copper nitrate + bromine

aqueous copper nitrate + heat $\rightarrow$ copper oxide + nitrogen dioxide

copper oxide + hydrochloric acid + zinc metal $\rightarrow$ copper metal + aqueous zinc chloride + hydrogen

After washing and drying the copper metal, I will mass the sample one more time in order to determine the amount of copper present in the original sample of compound.

Thus at each step I will know the mass of copper metal (constant) and the mass of each element (bromine or oxygen) that was combined in one of the compounds. By converting these masses to moles I can establish atomic ratios (chemical formulas) for each compound. Also, the masses of bromine in each compound can be compared in a ratio to illustrate the law of multiple proportions which states: in two different compounds containing the same two elements, the masses of the elements not held constant must be in a simple whole number ratio.

BAD

DATE	EXP. NUMBER	EXPERIMENT	
9-4-02		The Law of Multiple Proportions	01
NAME		LAB PARTNER	LOCKER NUMBER
Earl N. Meyer			

Purpose: to prove the law of multiple proportions

Method: A compound of copper and bromine (about 1 g) is to be heated to drive off the bromine in a few steps. Then the new compound will be dissolved in nitric acid and heated until another new compound forms, this one containing copper and oxygen. This compound will be dissolved in acid and reduced to copper metal by the addition of zinc. The masses of these various compounds will allow me to determine the formulas of the substances and prove the law of multiple proportions.

Discussion

I have tried to strike an obvious contrast without giving a completely ridiculous example. Students have actually written "pre-labs" such as the "bad" one in the past. It is fair to ask, "what is wrong with it?"

First, the purpose is too general. The experiment could be anything. All that has been done is to restate the title. You cannot "prove" anything with one experiment. Second, the entire method is written in passive voice. Students often favor this construction feeling that it sounds more "professional". A lab notebook is not a journal article. It is a personal record of work. Like a scientific diary. As such, the method is a way of organizing your thoughts and getting clear in your head what you will do. Passive voice makes no sense in such writing.

Third, the description of what is to be done is very mechanical, with no hint of chemical understanding or why this particular sequence is a logical way to achieve the purpose. It might as well be a recipe (even one amount is weakly given).

Finally, the entire headlong rush for the last period of the last sentence ends in a dying gasp since it is not clear at all what will be done with the collected data (is any being collected????). The method ends at the purpose statement. We know as little now as we did before we started.

MORAL: writing a good pre-lab is not a quick exercise you can do before class in the morning (or in the class before this one!)

One last comment on the pre-lab: missing from these examples are the tables that you could easily (and should easily) prepare BEFORE you come to lab. Preparing tables forces you to think about what measurements (or observations) you will need to achieve your purpose. But don't make your tables so small that you cannot cross out an entry and still have room for a legible second value. And USE A RULER.

The Post-Lab

This part of a lab report is what you do after all the practical work is done. At the end of many experiments there is a numbered list of calculations which--if followed--should lead to the information you need to make a conclusion. This list should be considered an outline at best. It is not acceptable to do something like this:

1. 0.9879 g
2. 0.8756 g
3. 0.7665 g
etc.

No one knows what "1." means. Label your calculations and use brief dialog when it will help the flow of your analysis. Be sure to include units and pay attention to significant digits. Here is an example:

1. mass of copper bromide sample = (sample + test tube) - test tube
= 18.7965 g - 17.8086 g = 0.9879 g copper bromide (1)

Any discussion of your calculated results is appropriate *whenever* you notice that things are going wrong or when you reach the end and need to compare with literature values, etc. Don't simply fill up a page with numbers. Be sure to include mention of error (be specific!) and touch on any other things listed in the conclusion section for the experiment.

In your finishing touches to an experiment be *brief* and to the point. More is not better unless you actually have something to say. Verbosity wastes your time and my time and is not endearing.