MATERIALS LABORATORY 1

Laboratory Reports: Format and Style

General remarks

Even outstanding technical work will see little application unless the results are communicated effectively. The purpose of a lab report, whether in a class or in professional research, is to explain concisely and thoroughly the important technical results of laboratory work. To accomplish this, a report:

1) presents results;
2) interprets results;
3) describes the engineering and scientific significance of the results.

Scientists and engineers use reports to contribute useful new information to the ever-growing body of scientific knowledge. In a class, the functions of a lab report are somewhat different:

1) to demonstrate to the instructor the student's understanding of the procedure, apparatus, and technical concepts involved in the experiment;
2) to give the student practice in communicating and interpreting experimental results.

In the classroom, unlike a professional setting, the information derived from experiments is seldom new, and the scientific principles involved are usually widely accepted. With a little prior reading, a student may be able to forecast accurately the results of his laboratory experiments; a practicing scientist, in general, cannot. The pitfall for a student is to consider the job to be complete if the experiment “worked,” i.e., if the results were as expected. Everyone involved strives for this, but it is not the point of the exercise. The point is to give the student a chance to set up, observe, and finally to understand certain physical phenomena.

When writing a lab report, the student should therefore adopt an attitude of testing the concepts that the experiment is intended to illustrate. This will help instill the objective frame of mind needed by all researchers: to explore all the information, explicable or not, contained in one's results. Classroom experiments are not likely to overturn any laws of science; but students are not as far as they might think from areas of inquiry that are by no means cut and dried.

Critical thinking, and the underlying knowledge it requires, must go hand in hand with objectivity. Don't trust data blindly: both expected and unexpected results could be spurious. Be alert to the experimental method: Are the apparatuses working properly? Are they calibrated and

being used under the conditions for which they are effective? Are all relevant variables being controlled? When these issues are settled, the student can confidently write the report, comparing and contrasting the results with existing information.

Grammar and mechanics

In brief: grammar, spelling, and neatness count. Strive for completeness, precision and conciseness.

Tense. The present tense is generally used in describing well-established facts (usually followed by one or more reference numbers), whereas the past tense is used when describing experimental results:

> "The melting point of pure lead is 327.4^{o}C [1,2]. In the present work, the melting point of the 100% Pb sample was 315^{o}C, indicating the possibility of impurities in the lead starting material."

Person. As logical as the use of the first person may seem at times ("We measured the electrical conductivity of germanium ..."), it is traditionally not used in scientific writing. This often forces the report writer to use the passive voice ("The electrical conductivity of germanium was measured ..."), contrary to the general recommendation that the active voice makes for stronger writing.[*] The second person ("When you compare the electrical properties of germanium to those of nickel .. .") is taboo in formal reports.

Format. Text should be double-spaced and on one side of the sheet only. Typewritten text is preferred, but neatly handwritten reports are acceptable. Minimum margins on all figures, tables, and text pages are I" at all edges.

Length. Remember that lab reports should be like swimsuits - brief enough to be interesting, but long enough to cover all the necessary parts. Those parts are described below.

Sections of a lab report

The following format is similar to that found in major professional materials science

[*] It also pressures the writer into referring to himself in the third person ("Lagerlöf has also shown…") when describing his previous work. The first person is appearing more frequently in such cases, though "we" and "our" is more common than "I" and "my." This is partly because few researchers work

journals: *Metallurgical Transactions, Journal of the American Ceramic Society, Journal of Macromolecular Science, Journal of Applied Physics,* and others. A useful guide to scientific report style, "How to Write and Publish a Scientific Paper" by Robert A. Day, (ISI Press, Philadelphia, 1979) provided some of the following information.

Abstract. The purpose of the Abstract is to provide a capsule account of the work, "to make a long story short." In 250 words or less, the Abstract:

1) States the principal objectives and scope of the investigation;
2) Describes the methodology employed;
3) Summarizes the results;
4) States the principal conclusions.

In professional practice, an abstract will be published separately from the rest of the paper. Often it is the only part of a paper many engineers or scientists will need (or have time) to read. For these reasons, the abstract should be self-contained, without any references to figures, tables, or other literature; and it should not state anything that is not mentioned again elsewhere in the paper. (This necessary redundancy is built into the format, as opposed to redundancy from careless writing, which should of course be avoided.) It is usually easiest to write the abstract after the rest of the report has been written.

Introduction. The purpose of the Introduction is to state the objectives and scope of the work reported. To accomplish this, the Introduction:

1) Describes the technical issues addressed by the work, placing them in their proper engineering or scientific setting;
2) Provides the necessary background information. In original research, this is accomplished by means of a literature review.
3) States the methods used in performing the work.

The Introduction can range from one to several pages in length depending on the nature of the work, but in experimental work is seldom longer than the Results and Discussion.

Experimental Procedure. The purpose of this section is to document the materials and procedures that were used in the study. This section should be complete, but brief. It should be sufficiently detailed that the reader knows exactly what the experimenter did, but not so long as to boring. Precisely describe samples (identities, amounts, sizes, preparation methods and materials), relevant experimental conditions (for example, temperatures, loads, voltages) and measurement uncertainties.

In professional research, the Procedure section should convince readers of the reproducibility of the results, and should provide enough detail to allow one's colleagues to repeat the experiments.

Results and Discussion. This is the most important section of the report. Its purpose is to present and interpret the results of the study. The results are the reason the report exists; the discussion should insure that their importance is appreciated by someone besides the authors. The effectiveness of all the other sections can be evaluated in terms of how well they set the stage for the Results and Discussion.

If there are only a small number of experimental results, these need only be written in the text. When the number of data is large enough that a verbal description would be unwieldy, tables and graphs are the most common means of presenting results. Tables are useful for distinct but related data for several parallel cases, such as in Table I below. Figures are more effective at illustrating the trends between independent variables (temperature and oxygen pressure in Figure 1) and dependent variables (electrical conductivity in Figure 1), and at illustrating the agreement between theoretical and predicted results (Figure 2).

Table I. Young's modulus (E) and ultimate tensile strength (σ_{ts}) of materials measured in this study.

Material	E (10^6 psi)	σ_{ts} (10^3 psi)
1010 carbon steel	30.0	64
4140 steel	28.0	108
2017 T351Al alloy	10.4	62
Gray iron 20	12.0	20
SiO_2 glass	10.5	16
Al_2O_3, polycrystalline	53.0	20-37
Al_2O_3, single crystal	-	71

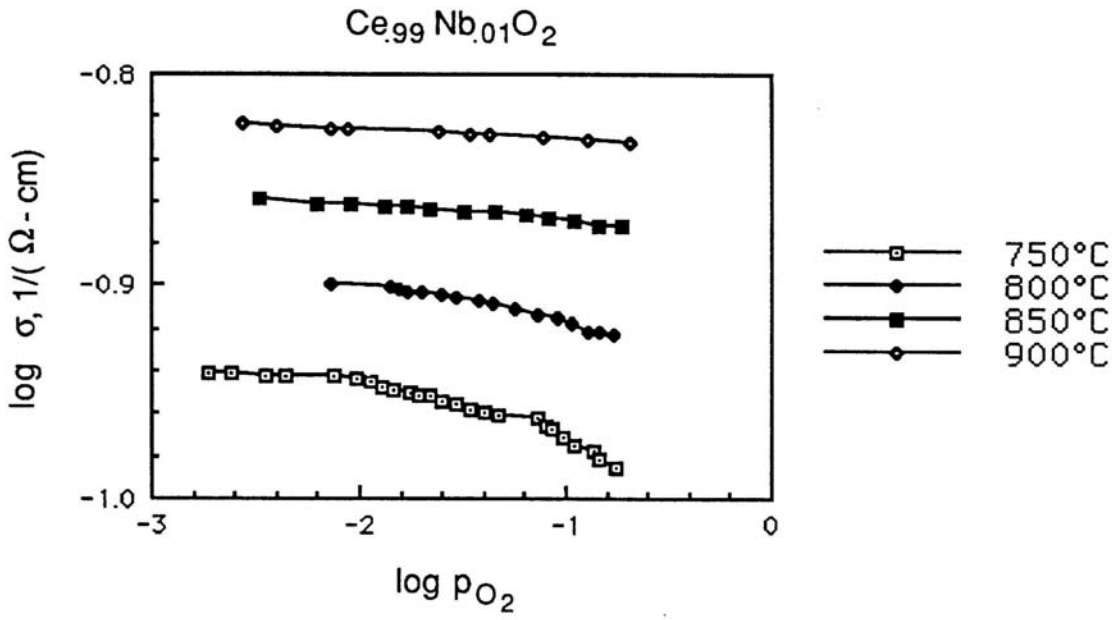

Figure 1. Electrical conductivity of $Ce_{0.99}Nb_{0.01}O_2$ versus PO_2 from 750 to 900 ^oC.

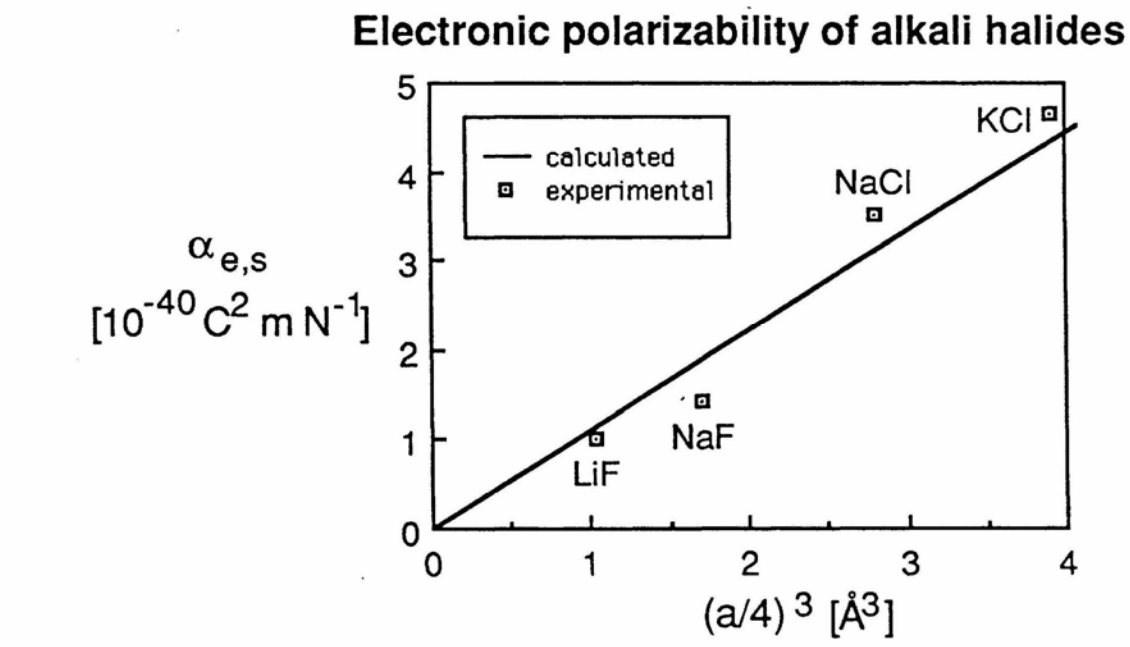

Figure 2. The dependence of ionic polarizability α on molar volume (a^3, where a is the lattice parameter) in several alkali halides.

Remember that each table or graph should be able to tell its own story without reference to the text. Each must have a self-explanatory caption and should be numbered sequentially (Roman numerals for tables, Arabic numerals for figures). Graphs must have all symbols defined, coordinate scales labeled, and units identified. Tables and graphs should be in ink. Graphs should be drawn on graph paper unless they are prepared by computer data plotting software. Finally, place all figures in the body of the text (on separate pages if necessary) as reference is made to them; do not collect all figures together in a separate section.

The Discussion should draw on the background information provided in the Introduction. Also, the current results should be compared or contrasted with related results from the scientific literature. In organizing the Discussion, it is helpful to address each independent/dependent variable pair one at a time. For example, Figure 1 illustrates two such relationships: temperature/conductivity and oxygen pressure/conductivity. The order in which these relationships are discussed may depend on the types of experiments performed, or whether certain topics serve as lead-ins to others. Every experiment described in the Procedure should be discussed in this section.

Care must be exercised not to draw inferences beyond the scope of the work performed. To extrapolate one's results to other conditions or materials is speculative and should be discussed as such.

Conclusions. The purpose here is to restate the major conclusions of the work. This section can be thought of as a distillation of the Results and Discussion. Like the Abstract, the Conclusions should be less than 250 words long, and cannot contain any material that is not stated in the Introduction or Results and Discussion. Whereas the Abstract briefly mentions the study's conclusions, they should be presented in more detail here, though not at as much length as in the Discussion.

References. Since science builds on the knowledge of the past, it is essential to refer to the work of others for the purposes of comparing, augmenting, and corroborating one's current results and placing them in a larger scientific or engineering context. The purpose of this section is to list those references, which should be cited by number in the body of the report. Use the following forms:

Journal article (e.g., from volume 197, issue 6, pp. 190-191 of the 1987 Transactions of the American Humane Society):

A. B. Smith and C. D. Jones, “The Care and Feeding of Materials Scientists,” Trans. Am. Humane Soc. 197 [6] 190-1 (1987)

Book:

J. Kuhl, “How to Succeed in Materials Science Without Really Trying,” pp. 693-702. John Wiley & Sons, New York, 1975

Article in a book or conference proceeding:

S. Brown, M. Green, and W. White, “Stained Glass,” pp. 105-45 in Recent Developments in Ceramic Colors, ed. by R. G. Biv. Spectrum Press, London, 1968.

Direct quotes must be enclosed in quotation marks and properly referenced. The sources of specific experimental results, figures, and tables taken from references must be also be identified by citing the appropriate numbered reference. Overall, however, the report must represent the student's original analysis of the experiment.

Accurate and complete citations not only give credit where it is due, but also add considerably to the reference value of the report to others who wish to study the subject.

Appendices. Sometimes lengthy procedures, derivations, or tables need to be documented, but they would draw attention away from the main findings of the report if included in the body of the text. These are included in one or more Appendices at the end of the report and referred to in the main text as needed.