THE LABORATORY NOTEBOOK

In scientific work keeping a permanent record of all raw data, observations, calculations, et cetera obtained during an experiment is important. Therefore, a student must become proficient at keeping a good laboratory notebook as a requisite for the General Chemistry laboratory course. The following notes should help you prepare your notebook for each experiment.

GENERAL INFORMATION

Type of Notebook Required: A duplicate page notebook is required; carbon copies are turned over to the TA for grading while original pages remain bound in the student's notebook. The notebook must be numbered and bound (no loose or spiral pages). Pages may not be torn from the book with the exception of the duplicate copy turned in to the TA during each lab period. Square ruled paper is preferred for graphing.

Format: Do not use pencil; all entries must be made in INK. When an error occurs, correct it by drawing a SINGLE LINE through the incorrect entry and writing the corrected entry nearby. An error is NEVER erased or obliterated because it may be necessary to retrieve the original entry at a later date. Remember, this is a "work-in-progress" notebook and is not expected to resemble a finished manuscript. Only the front side of each page is used for pertinent information or experimental data. The back side of the page can be used for quick calculations or personal notes. A single diagonal line should be drawn though any unused portion of a page and initialed to prevent improper entry of data after an experiment is completed.

Notebook Purpose: The first page of the notebook is reserved for a statement summarizing the content and purpose of the notebook. The title and dates of the course must be indicated here.

Table of Contents: The second page is reserved for a Table of Contents. Update this table with the Title and page of each experiment as it is completed.
BEFORE COMING TO LAB:
Label all pages with the title of the experiment, your name, ID#, TA name, and date:

1. **Experiment Title and Source:** On a fresh page enter the title of the experiment and reference source at the top of the page (in addition to the information already required in italics above).

2. **Objective:** Write a *brief* description of the problem under investigation and the method to be used to investigate the problem. Include pertinent formulas or equations.

3. **Chemicals, Equipment, and Table of Physical Constants:** List the chemicals with any pertinent constants (molecular weights, boiling points, etc) and equipment needed. Reference any source (such as the “CRC Handbook”, a textbook, or a chemical manufacturer’s website) used.

4. **Procedures:** Write a BRIEF series of steps for the experimental procedures. These steps should not be extensive since detailed procedures can be found in the lab manual. A preferred style is to divide the notebook page in half, writing procedure steps on the left side of the page and reserving the right side for observations.

5. **Experimental Data:** If extensive numerical data is to be recorded, a table should be set up in advance to organize the data. (See "Organizing Data".)
IN LAB:

6. Recording Data and Observations: All observations must be recorded DIRECTLY into the notebook. Data recorded on scraps of paper (such as paper towels) is unacceptable and will be confiscated by the TA. Entries should be clear and concise. Use descriptive words such as "vigorous gas formation" or "deep pink color". If using an analytical instrument, record the name of the manufacturer, instrument number etc. (See "Recording Data"). When working with a partner or a group, record the names of the other students. Data and observations should be well organized and easy to read. When recording numerical data, use units and significant figures to express the scope and sensitivity of the measurement.

Recall the definition of significant figures: certain numbers (numbers from the markings on the measuring device) + one uncertain number (number estimated between the markings).

- Buret volumes should be recorded to the 2$^{nd}$ decimal place (watch for round-offs)
- Volumetric pipet and flask volumes $\leq$ 100 mL should be recorded to the 2$^{nd}$ decimal place.
- Volumetric pipet and flask volumes $>$ 100 mL should be recorded to the 1$^{st}$ decimal place.
- Graduated cylinder and temperature readings depend on the sensitivity of the device used.
- Percent transmittance should be read to at least one decimal place.
- Low absorbance readings should be read to one decimal place. Large absorbance values can only be recorded to the unit because they are logarithmic functions.

POST LAB:

7. Calculations and Graphs: Calculations and graphs should follow the data section. When doing repetitive calculations, show one example complete with units and chemical formulae where appropriate. Computer-generated graphs must be created with the correct scale to represent the scope of the collected data. Include title, labeled axes, and units. Curves through data points must be smooth lines and not "dot-to-dot" connections. (See "Graphing Techniques").
8. **Postlab Questions, Discussion, and Error Analysis:** Postlab questions and their answers are usually an adequate discussion of the meaning behind the data and observations of the experiment. Briefly describe any procedural changes or unexpected observations. Analyze possible sources of error if results appear inconsistent. (See: "Analysis of Errors"). If a true value is available for comparison, calculate percent error and discuss why your results may differ from true value. The source of systematic errors must be recognized in order to avoid them in subsequent experiments. (Random errors are usually more difficult to eliminate.)

9. **Conclusion:** The conclusion must be a brief, objective, scientific summary of the findings of the experiment. It must be supported by the data and should not be an expression of the expectations of the student. The conclusion should NEVER contain personal statements such as "I enjoyed this experiment very much..." or "this experiment taught me...." etc.

**NOTEBOOK GRADING:**

A good lab write-up should take no more than 3-6 pages. Not all of the information in items 1-12 is required for each experiment; the student must judge what is necessary for a good experimental notebook.

When grading notebooks, Teaching Assistants will be looking at:
- Preparation before lab begins (intro, procedural steps etc.)
- Quality of observations
- Recording measurements with correct number of sig figs and units
- Organization of data
- Precision and accuracy of data
- Presentation of data in graphs
- Calculations
- Discussion and assessment of errors
- Conclusions that are supported by data
TA's will also be assessing notebooks on the more general criteria: Using ONLY the notebook as a guide,

- Could another student understand what problem was investigated, assemble chemicals and equipment, perform the experiment, and acquire the same data or make the same observations?
- Could a comprehensive, formal laboratory report of the experiment be written one year later?
- Would you be able to devise an experimental procedure to solve a similar lab problem and carry it out to a successful conclusion or work a similar problem in a lab examination?

Remember a lab notebook is a WORKING TOOL for the lab. You will make recording errors and pages will be stained with chemicals. The CONTENT is what counts.

A NOTEBOOK EXAMPLE

The notebook example on the next page is for an experiment to measure the density of a set of glass beads. The experiment required students to form their own set of procedures. Although the example appears in typed form below, it originally appeared in a student's lab manual with the typical ink spots, cross outs, etc. that occur during a normal lab period.
**Experimental Flow Chart:**

1. **0.000 g**
   - Tare 25 mL beaker on scale.

2. **2.880 g**
   - Add beads and record mass.

3. **Fill buret 1/3 full, record initial volume.**
4. **Add beads from above, record final volume.**

Repeat for a total of 5 trials.
**Title:** The Density of Glass Beads

**Source:** Chem 1L website, http://eee.uci.edu/programs/gchem/

**Purpose:** Partners will determine the density of the glass beads. Density is a property of matter defined as the mass per unit volume: \( D = \frac{m}{V} \). The glass beads are solid spheres approximately 5 mm in diameter with a true density of 2.40 g/mL.

**Equipment:** Volumetric burets and the contents of the student lockers can be used.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. With a partner, determine procedure.</td>
<td>Partner: John Garcia</td>
</tr>
<tr>
<td>2. Fill buret to 1/3 volume with water. Record initial volume.</td>
<td>See table below.</td>
</tr>
<tr>
<td>3. Weigh set of 10 dry beads.</td>
<td>Beads appear to be identical, clear, colorless solid glass approximately 5 mm in diameter. On balance #2 (Mettler balance), tared 25-mL beaker and then added beads. Masses recorded in table below.</td>
</tr>
<tr>
<td>4. Add beads to buret and measure final volume.</td>
<td>Read buret volume from top down. Stopcock leaks- replaced with new one from stockroom. Tapped sides of buret to dislodge trapped air bubbles with each set of beads. Volumes recorded in table below.</td>
</tr>
<tr>
<td>5. Continue to weigh 4 additional sets of glass beads, adding each set to buret and measuring new volumes.</td>
<td>Each member took turns reading buret levels. Group verified each reading. See table for data.</td>
</tr>
</tbody>
</table>
Data:

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of 10 beads (g)</td>
<td>2.880</td>
<td>2.884</td>
<td>2.731</td>
<td>2.883</td>
<td>2.807</td>
</tr>
<tr>
<td>Initial Volume (mL)</td>
<td>38.70</td>
<td>37.50</td>
<td>36.33</td>
<td>35.18</td>
<td>34.00</td>
</tr>
<tr>
<td>Final Volume (mL)</td>
<td>37.50</td>
<td>36.33</td>
<td>35.18</td>
<td>34.00</td>
<td>32.84</td>
</tr>
<tr>
<td>Volume of 10 beads (mL)</td>
<td>1.20</td>
<td>1.17</td>
<td>1.15</td>
<td>1.18</td>
<td>1.16</td>
</tr>
<tr>
<td>Density (g/mL)</td>
<td>2.40</td>
<td>2.46</td>
<td>2.37</td>
<td>2.44</td>
<td>2.42</td>
</tr>
</tbody>
</table>

Calculations:

Average Density = \( \frac{2.40 + 2.46 + 2.37 + 2.44 + 2.42}{5} \) = 2.42 g/mL

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>Density (g/mL)</th>
<th>Deviation</th>
<th>Square of Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>2.40</td>
<td>-0.02</td>
<td>0.0004</td>
</tr>
<tr>
<td>(2)</td>
<td>2.46</td>
<td>+0.04</td>
<td>0.0016</td>
</tr>
<tr>
<td>(3)</td>
<td>2.37</td>
<td>-0.05</td>
<td>0.0025</td>
</tr>
<tr>
<td>(4)</td>
<td>2.44</td>
<td>+0.02</td>
<td>0.0004</td>
</tr>
<tr>
<td>(5)</td>
<td>2.42</td>
<td>0.00</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Standard Deviation = \( \sqrt{\frac{0.0004 + 0.0016 + 0.0025 + 0.0004 + 0.0000}{5 - 1}} \) = 0.035

Percent Error = \( \frac{(2.42 - 2.40)}{2.40} \times 100 \) = 0.833%

Graph: The data below represent the sum of mass and volume for additive sets of beads in experiments #1-5. The data is graphed as \( \Delta m \) versus \( \Delta V \). The slope of the line is equal to the density: \( \Delta m = D\Delta V \)
<table>
<thead>
<tr>
<th>Number of Beads</th>
<th>$\Delta m$ (g)</th>
<th>$\Delta V$ (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.880</td>
<td>1.20</td>
</tr>
<tr>
<td>20</td>
<td>5.764</td>
<td>2.37</td>
</tr>
<tr>
<td>30</td>
<td>8.495</td>
<td>3.52</td>
</tr>
<tr>
<td>40</td>
<td>11.378</td>
<td>4.70</td>
</tr>
<tr>
<td>50</td>
<td>14.185</td>
<td>5.86</td>
</tr>
</tbody>
</table>

**Discussion and Sources of Possible Errors**

John Garcia and I decided to measure the mass of the dry glass beads on the balance by using a 25-mL beaker as a container and taring the mass of the container so that the mass of the beads could be read directly. This method was chosen to avoid calculation errors that could arise from weighing by difference. The volume of the solid was determined indirectly by placing the solid in water and measuring the volume of water displaced by the solid. The volume of the displaced water was assumed to be equal to the volume of the solid. We decided to use a 50-mL volumetric buret as the water container because the change in volume can be estimated to the hundredth of a milliliter. This was more precise than the graduated cylinder which could only be estimated to the tenth of a milliliter.
The glass beads provided for the experiment were clear, colorless, solid spheres approximately 5 mm in diameter. The true density is 2.40 g/mL. Since the volume displaced by a single glass bead was small, the mass and volume of 10 glass beads was measured as a single set to minimize the volume error. Because it required an estimate of the last digit, a volume measurement was not recorded until the "group" reached a consensus. There was also some initial difficulty with a leaking stopcock (which was replaced) and with trapped air bubbles between the glass beads. The trapped air bubbles were dislodged by tapping the sides of the buret and waiting until they dispersed.

The density was determined by two methods: calculation and linear plot. The calculation method gave an average density value of 2.42 ± .035 g/mL. The standard deviation is a measure of the range of error in the measurements. The slope (density) of the linear plot was 2.42 g/mL. The best-fit line smoothes out random error in the measurements. The extrapolated line did not exactly pass through zero but was very close (the y-intercept was equal to –0.0117). Using the true value for density (2.40 g/mL) it was determined that the percent error was 0.833%.

**Conclusion:** The average density of the glass beads determined from five sets of measurements is 2.42 ± 0.35 g/mL. The percent error calculated from true value is 0.833%.