The Laboratory Notebook

A laboratory notebook should be used to explain laboratory procedures, record all laboratory data, show how calculations are made, discuss the results of an experiment, and to explain the theories involved.

A record of laboratory work is an important document which will show the quality of the laboratory work that you have done. You may need to show your notebook to the Chemistry Department at a college or university in order to obtain credit for the laboratory part of your Advanced Placement Chemistry course. As you record information in your notebook, keep in mind that someone who is unfamiliar with your work may be using this notebook to evaluate your laboratory experience in chemistry. When you explain your work, list your data, calculate values and answer questions, be sure that the meaning will be obvious to anyone who reads your notebook.

Procedure

1. Use a 1 to 1 ½ inch three ring binder. This is not your class binder.

2. Write your name and class on the first, or cover page in the binder.

3. In ink, number all the right-hand pages on the lower right corner.

4. Save the first three pages for a Table of Contents. This should be kept current as you proceed. Each time you write up a lab, place the title and page number where the lab report begins in the Table of Contents.

5. Write in ink. Use only the right hand (front) pages. You may use the left-hand pages for preliminary notes or for a quick graph. The left-hand pages will not be graded.

6. If you make a mistake DO NOT ERASE. Just draw ONE LINE (~~ONE LINE~~) through your error, and continue. It is expected that some errors will occur. You cannot produce a perfect, error-free notebook. Errors should be corrected by drawing one line through the mistake, and then proceeding with the new data.

Laboratory Reports

Include the following information in your laboratory reports:

1. **Title.** The title should be descriptive. *Experiment 5* is not a descriptive title.

2. **Date.** This is the date (or dates) you *performed* the experiment.

3. **Purpose.** A brief statement of what you are attempting to do and want to find out about the materials or concept.

4. **Procedure.**
A one to four sentence description of the method you are using. You may refer to the lab manual for specific instructions, but you should include a brief statement of the method. Do not include lengthy, detailed directions. A person who understands chemistry should be able to read this section and know what you are doing.

5. **Data.**
Record all your data directly in your lab notebook on the right-hand pages. Organize your data in a neat, orderly form. Label all data very clearly. Use correct significant digits, and always include proper units (g, mL, etc.). Underline, use capital letters, or use any device you choose to help organize this section well. Space things out—don't try to cram everything on one page. Use tables where appropriate.

6. **Calculations and Graphs.**
You should show *how* calculations are carried out. Give the equation used and show how your values are substituted into it. Give the calculated values. If graphs are included, make the graphs an appropriate size. Label all axes and give each graph a title. If experiments are not quantitative, this section may be omitted.

7. **Conclusions.**
Make a simple statement concerning what you can conclude from the experiment. The final results of the experiments should be in the conclusion.

8. **Discussion of Theory.**
In this section you should include such information as: What theory was demonstrated in this experiment? What do the calculations show? How was the purpose of the experiment fulfilled? Why did (or didn't) the experiment work? Refer back to the purpose of the lab to write this section.

9. **Experimental Sources of Error.**
What are some *specific* sources of error, and how do they influence the data? Do they make the values obtained larger or smaller than they should be? Which measurement was the least precise? Instrumental error and human error exist in all experiments, and should not be mentioned as a source of error unless they cause a significant fault. Significant digits and mistakes in calculations are NOT a valid source of error. In writing this section it is sometimes helpful to ask yourself what you would do differently if you were to repeat the experiment and wanted to obtain better precision. If you can calculate a percent error or percent deviation, do so and include it in this section.

10. **Questions.** Answer any questions included in the lab directions. This may include both pre- and post-lab questions.

Reporting Laboratory Data

Graphing Experimental Data

1. All graphs should have a descriptive title ("Graph" is not a title).

2. Both the vertical and horizontal axes should have labels and units clearly marked. Use a ruler to draw the axes.

3. The scales chosen should reflect the precision of the measurements. For example, if temperature is known to be ±0.1 ^{0}C, you should be able to plot the value this closely. Don't have each block of the graph equal to 10^{0}C. You may need to use graph paper with smaller divisions than that in the laboratory notebook.

4. There should be a table in which the data values are listed. Don't put data in a graph unless you have first listed it in a table.

5. The controlled or independent variable is conventionally placed on the horizontal axis. The dependent variable is graphed on the vertical axis.

6. There should be an obvious small point on the graph for each experimental value. It is not necessary to include the coordinates of each point since they will be in the data table.

7. A smooth line should be drawn that lies as close as possible to most of the points. Do NOT draw a line connecting one point to the next one as in a dot-to-dot drawing. If the line is a straight line, use a ruler to draw it.

Uncertainty

Every experimental value has some uncertainty associated with it. The amount of uncertainty depends on two things: the precision of the instrument used to make a measurement, and the skill of the person using the instrument.

Plus-or-Minus Notation

The uncertainty of a measurement can be expressed using plus-or-minus notation. For example, an object whose mass is determined on a centigram balance may be found to have a mass of 3.40 ±0.01 gram. The same object, when measured on an analytical balance, may have a mass of 3.4124 ±0.0001 g. The plus-or-minus notation reflects the precision of the balance used for making the measurement.

Significant Digits

Often, the plus-or-minus notation is not used when reporting a measured value. Instead, the significant digit notation is used. When properly assigning significant digits, include all measured digits that are known with certainty and one digit that is an estimate. In the above examples, the mass of the object on the centigram balance should be reported as 3.40 g, and on the analytical balance as 3.4124 g. The last digit in both measurements has some uncertainty. Notice that a final zero is included in the value 3.40 g because this was a measured number. Use the rules for addition, subtraction, multiplication and division of values with significant digits in carrying out your calculations.

Accuracy

Accuracy is a measure of how close an experimental value is to a value which is accepted as correct. The measure of the accuracy of an experimental value is reported as Absolute Error or Percent Error.

Absolute error is just the difference between the measured and accepted values:

Absolute error = Experimental value - Accepted value

Percent error or Relative error is calculated as follows:

$$\%\ \text{error} = \frac{(\text{Experimental value} - \text{Accepted value})}{\text{Accepted value}} \times 100\%$$

Notice that the error is a positive number if the experimental value is too high, and is a negative number if the experimental value is too low. Some instructors prefer that the absolute value of the percent error be used, thus always giving a positive value.

Precision

Frequently in science, an accepted or true value is not known. The accuracy of a measurement cannot be reported if an accepted value is unavailable. Since scientists don't know how close they are to the true value, they repeat their experiments several times and report on how close together their values lie. It is hoped that an experiment that can give reproducible results will also give accurate results. Certainly, if data cannot be reproduced, it cannot be reliable.

Precision is a measure of how reproducible experimental measurements are. Precision is reported as Deviation or Difference of values.

Deviation or Difference

The Absolute Deviation or Absolute Difference of each measurement is the difference of each measurement from the mean or average:

$$\textbf{Absolute deviation} = |\textbf{Measured value} - \textbf{Mean}|$$

The Average Deviation or Average Difference is the average of all of the absolute deviations.

$$\textbf{Average Deviation} = \frac{\Sigma \text{ absolute deviations}}{\text{\# of trials}} \qquad (\Sigma \text{ means sum of })$$

The Percent Deviation or Percent Difference is the average deviation reported as a percentage:

$$\begin{array}{l}\textbf{Percent Deviation} \\ \textbf{or Average Deviation}\end{array} = \frac{\text{Average Deviation}}{\text{Mean}} \times 100\%$$

For example, antacid tablets were analyzed to find the amount of sodium carbonate present. The experiment was carried out three times, and the following values were found:

Trial 1 1.69 g
Trial 2 1.74 g
Trial 3 1.68 g

The **Mean** or Average of the values is

$$\text{mean} = \frac{1.69 + 1.74 + 1.68}{3} = 1.70 \text{ g}$$

The **Absolute Deviation** of each value from the mean is:

Trial 1 $|1.69 - 1.70| = 0.01$ g
Trial 2 $|1.74 - 1.70| = 0.04$ g
Trial 3 $|1.68 - 1.70| = 0.02$ g

The **Average Deviation** is:

$$\text{Average Deviation} = \frac{0.01 + 0.04 + 0.02}{3} = 0.02 \text{ g}$$

The **Relative Deviation or Relative Difference** is:

$$\text{Relative Deviation} = \frac{\text{Average Deviation}}{\text{Mean}} \times 100\%$$

$$\text{Relative Deviation} = \frac{0.02 \text{ g}}{1.70 \text{ g}} \times 100\% = 1.2\%$$

This tells the scientist that on the average, the experiment will give values that are within 1.2% of the average (and hopefully true) value.