Critical and Analytical Thinking in Science: Data Analysis

Learning how to analyze data to get meaningful results and draw conclusions from those results is one very important objective in this course. One way to learn and develop critical thinking skills is to try to prove or disprove a hypothesis. According to the American Heritage Dictionary, New College Edition, Houghton Mifflin, 1979, a hypothesis is "an assertion subject to verification or proof, as:
a. a proposition stated as a basis for argument or reasoning.
b. a premise from which a conclusion is drawn.
c. a conjecture that accounts, within a theory or ideational framework, for a set of facts and that can be used as a basis for further investigation."
In each lab, you will be presented with one or more problems to solve. For each problem, there is a hypothesis for you to prove or disprove. In general, you will prove or disprove a hypothesis by doing the following:

1. collect data from an experiment that is relevant to the hypothesis;
2. analyze the data, usually by calculations using chemical principles, to obtain results;
3. interpret your experimental results to determine the validity of the hypothesis.

Using a hypothesis makes you focus on the important experimental variables and helps you understand how chemical principles are used in the experiment. To help you analyze data, you can represent your data and results in the form of tables or graphs or both to help you see trends and patterns in the data and results. We will also be collecting data by computer to enable you more time to analyze data in lab. Also, you will learn to find information from various information sources and use that information to help you prove or disprove hypotheses and draw conclusions.

Representing Data and Results in Tables and Spreadsheets and with Graphs

In each lab, you will be making observations - some qualitative and some quantitative. For the quantitative observations, you will attach numbers to your observations. You will analyze your numerical data by doing calculations to get results. Then, you will interpret your results, i.e., figure out what these numbers mean, to draw conclusions about your experiment. You will record all of this information in your lab notebook.

Tables

You will want to organize your data and results in a way that makes it easy for you to read and interpret as well as another person who looks at your lab notebook. Preparing a table is an excellent way to organize your data and results. In general, a table will show data in columns (as opposed to rows). For example, see Table 1 on p. 12 of this Lab Manual. Note that this table consists of two columns: Measuring Devices and Uncertainty. Each device is clearly listed with its corresponding uncertainty.

When you prepare a table, do the following:

1. Give the table a specific number and title, e.g., "Table 1. Uncertainties of Various Measuring Devices" is a good title whereas "Devices" is not specific and doesn't state what information is shown in the table.
2. Label each column (or row) with the appropriate units. Use the appropriate number of significant figures.
3. Make your table legible.

Spreadsheets

In the lab, we will prepare tables using Microsoft Excel spreadsheets. You can program Excel to do calculations that help you analyze data. For example, you can multiply the number in one cell (A1) by a number in another cell (B1) to give you the product in a third cell (C1). Of course, you can also do this on your calculator. However, the advantage of Excel becomes evident when you have a big set of data. If you have the same calculation to do 10 times, you can have Excel to do it for you very quickly.

Cell	A	B	C
1	3	5	15

type in "=A1*B1" in cell C1 or use the Formula wizard

After you prepare your Excel spreadsheet/table, print it out and staple it into your notebook.

Graphs

Often, you will want to show the data you have organized in a table in a graph. A graph is another excellent way to represent data. A graph can show trends in your data or results that you may not see from a table. The data that is represented in a graph can give you a result. For example, in Lab 1, you will graph mass of water on the y-axis and volume of water on the x-axis. The slope of this line gives you the result you are looking for. The slope includes data from all of your data points. Another way to do this is to individually calculate the mass/volume and then take the average. However, the graph gives you this information quickly and also gives you information about the error in your experiment.

For every graph that you do, do the following:

1. Give your graph a specific number and title, e.g., "Graph 1. Graphical determination of _____ from mass and volume."
2. Label each axis with the appropriate quantity and show the units.
3. Label the divisions on your graph paper so that an individual, e.g., your instructor, who attempts to interpret the graph, may easily interpret each data point. Furthermore, the divisions should be laid out so that the graph covers most of the graph paper.
4. Usually, you will not want to just show data points. You may draw a smooth curve through your data points (do not connect the data point) or fit a straight line (with a linear regression analysis) through your data points.

You can graph your data using the Graphical Analysis software. You enter your data in a table and this software automatically graphs the data for you. You can do a linear regression using this software or fit your data to other math functions. Then, you can print out your graph and staple it into your notebook.

Computer-Assisted Data Acquisition

You will acquire data and take measurements using a computer for several experiments using Vernier Science and Technology hardware and software. You will take temperature, conductivity, pH, and pressure readings using the appropriate sensors and probes. To make these measurements, you will need the following equipment:

1. Computer with Vernier LoggerPro software
2. Vernier LabPro hardware interface
3. AC power adapter (output: 6 V DC at 600 mA) for the LabPro.
4. USB cable that connects LabPro interface to the computer
5. Appropriate probe that connects to LabPro interface

Your lab instructor will help you connect the probe to the computer.

Open the Vernier folder (which should be on the computer desktop), and double click on the LoggerPro icon. The interface and software automatically senses the probe that is connected to the computer.

You will also use the Ocean Optics Chem 2000 UV-VIS spectrophotometer to measure absorption and emission spectra (the amount of light absorbed or emitted by a sample at each wavelength). Each spectrophotometer is connected to a computer. To use the Chem 2000, you will need:

1. UV-VIS (deuterium tungsten) light source and integrated cuvette holder.
2. Spectrophotometer detector.
3. Fiber optic cable that connects light source and holder to the spectrophotometer detector.
4. Serial cable that connects the light source and holder to the spectrophotometer detector.
5. USB cable that connects the spectrophotometer detector to the computer.
6. AC power adapter (output: 12 V DC at 1.25 A) for the UV-VIS light source.
7. A cuvette for your sample.

Your lab instructor will help you connect the Chem 2000 to the computer.

Double-click on the OOIC icon on the desktop (if the OOIC icon is not on the desktop, it will be in the Ocean Optics folder) to open the Ocean Optics software to collect spectra.

Chemistry References

There are many reference sources in science and chemistry. Here are a few common references that are available in the chemistry lab:

1. CRC Handbook of Chemistry and Physics. This reference compiles a lot of science information in one book.
2. Merck Index.
3. Chemical vendor catalogs.

Internet Access in the Chemistry Lab

There are 12 computers in each chemistry lab. These computers are for chemistry students to use. To log onto the Hartnell College network, use the username shown on the top of monitor. The password is: hartnel.

You will use several chemistry websites to look up information. Here are some websites of interest in chemistry:

1. Chem 1B website (http://ccchemteach.com). See the Weblinks.
2. Los Alamos National Laboratories Periodic Table of the Elements (http://periodic.lanl.gov/default.htm). Click on an element for more information.
3. Wolfram Alpha (http://www.wolframalpha.com/), Chemicalland21 (http://chemicalland21.com/), and Wikipedia (http://en.wikipedia.org/wiki/Main_Page). Enter the name of a substance and you can get information on properties, structure, and references to other information.
4. Material Safety Data Sheets (http://hazard.com/msds/). Type in a chemical name and get the MSDS of that substance.
5. Chemistry Data Tables (http://www.wiredchemist.com/chemistry/data/chem_data.html). This web site includes thermodynamic properties of elements, compounds, and ions; solubilities of ionic compounds in water.
6. National Institutes of Standards and Technology Chemistry WebBook (http://webbook.nist.gov/chemistry/). This site provides thermochemical, thermophysical, and ion energetics data compiled by NIST under the Standard Reference Data Program.