Experiment 8
Graphing

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Name:

Date:

Key Objectives

1. Graph experimental data.
2. Make a "good" looking graph.
3. Labeling and numbering of axis.
4. Adding a curve-fit to a graph.

Discussion

It is often said that a picture is worth 1,000 words, or for scientists we might rephrase it to say that a graph is worth 1,000 words. Graphs are most often used to express data in a clear, concise and meaningful way. Trends are readily apparent, and information is easy to extract. In today's laboratory we will learn how to properly present data in a graphical format. Graph terminology, basic graph features, basic graphing skills using excel, and general graph functions will be mastered.

> A picture is worth a thousand words.
> -unknown

> If a picture is worth a thousand words, please paint me the Gettysburg Address
> -Leo Rosten

Various types of graphs are possible, the most common type uses the Cartesian coordinate system to show the relationship between two variables, the independent (x) and dependent (y) variables. The independent (x) variable is generally controlled by the experimenter (or naturally increments) and is plotted on the x-axis (horizontal axis) while the dependent (y) variable changes as the independent variable changes and is generally plotted on the y-axis (vertical axis). The goal of any graph is to maximize the amount of data shown in the space provided.

A. Graph Terminology

The terminology used in making graphs may be new to many of you. Figure 8.1 shows features commonly found on graphs.

1. X-axis: Generally the independent variable is plotted on the horizontal axis.

2. Y-axis: Generally the dependent variable(s) are plotted on the vertical axis.

3. Title: A general description of what is being graphed.

4. Axis Title: Titles for X and Y axis. The title should include a Label for what you are plotting and the Units you are plotting with.

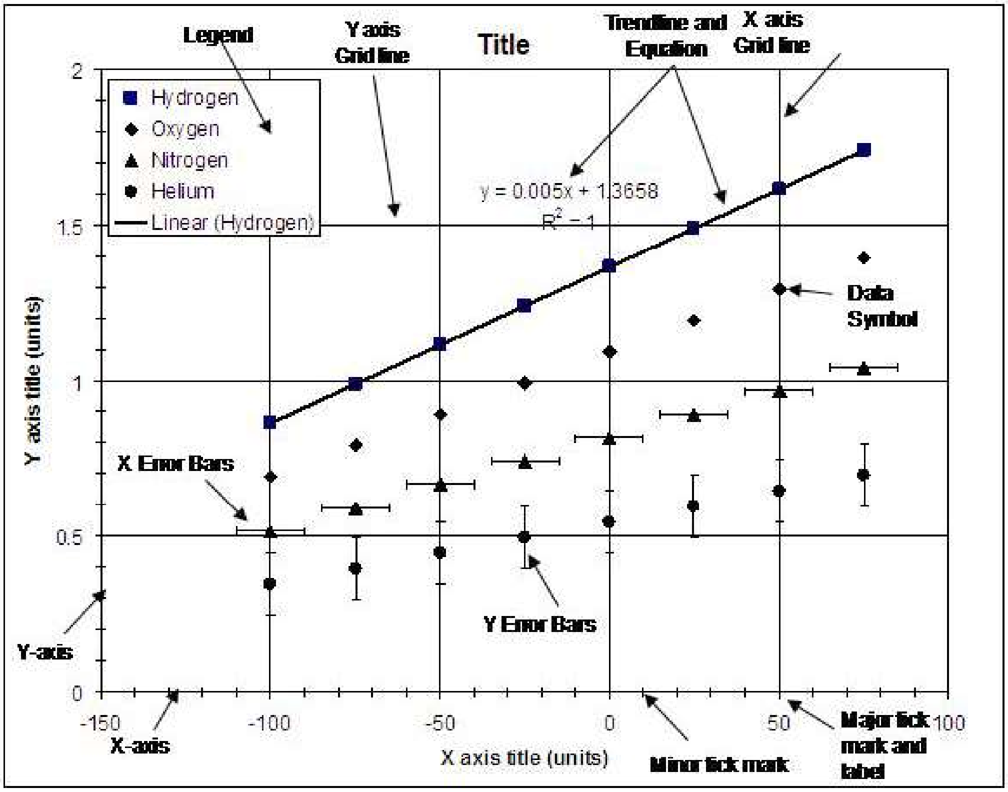

Figure 8.1: Anatomy of a graph. credit: author

5. Legend: Describes the independent variables being graphed. It includes the symbol representing each individual variable and a description or identifier.

6. Grid Lines: Lines on the graph drawn parallel to the X or Y axis. They generally are used as guides for the eye to make it easier to see the value of data points.

7. Tick Mark: Small hash mark on X or Y axis that denotes a specific value. Major: A label and grid line are normally drawn here. Minor: Normally just a tick mark on axis to indicate smaller units. Normally not labeled or given grid lines.

8. Tick Label: Label associated with tick marks on the X and Y axis.

9. Data Symbols: Symbols used to mark the data points on a graph.

10. Error bars: Horizontal bars (X error bars) or vertical (Y error bars) sometimes found attached to data points indicating the error involved in the measurement.

B. Good vs. Bad Graphs

A good graph is designed to convey a large amount of information in a small space. It is important to make full use of the space provided to maximize the information. An example of a good graph is shown in Figure 8.2. Several design goals are listed below.

1. Title - All graphs should have a title which conveys what is being graphed.

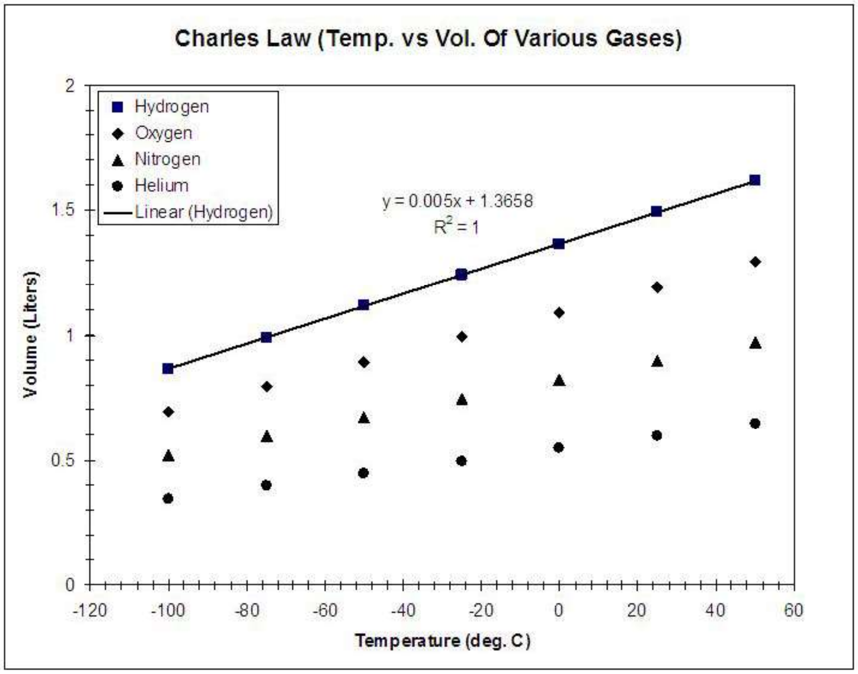

Figure 8.2: An example of a good graph. credit: author

2. Labels - All graphs should have both axis properly labeled with what is being plotted and the units.

3. The x and y axis should use convenient units (both major and minor). The X and Y axis labels are reasonably spaced (i.e. not too close together or too far apart).

4. Legend - All graphs should include a legend if more than one set of data is being plotted that provides information about the different data sets.

5. Text should be readable. Don't use fancy fonts or fonts too small to read.

6. Symbols used for data points should be:

    (a) Proper size (not too big or small)

    (b) Proper color (easy to distinguish). Generally use black and white only as people may not be able to print graphs in color.

    (c) Proper shape (don't use crosses or dashes and avoid open symbols when possible)

    (d) Avoid using duplicate shapes in different colors. It looks fine on a computer screen but if printed in black and white it will be impossible to distinguish between them.

7. Maximize the size of your graph. It is often convenient to drag the Legend inside the graph so that you can resize the graph and make it larger and easier to read.

We will look next at several bad graphs. Figure 8.3 has several things wrong with it.

1. No title
2. Missing label on Y axis
3. Missing units on X axis
4. No legend
5. X axis units are too close together, overlap, and are nearly impossible to read.
6. Y axis units are spaced so far apart they are useless

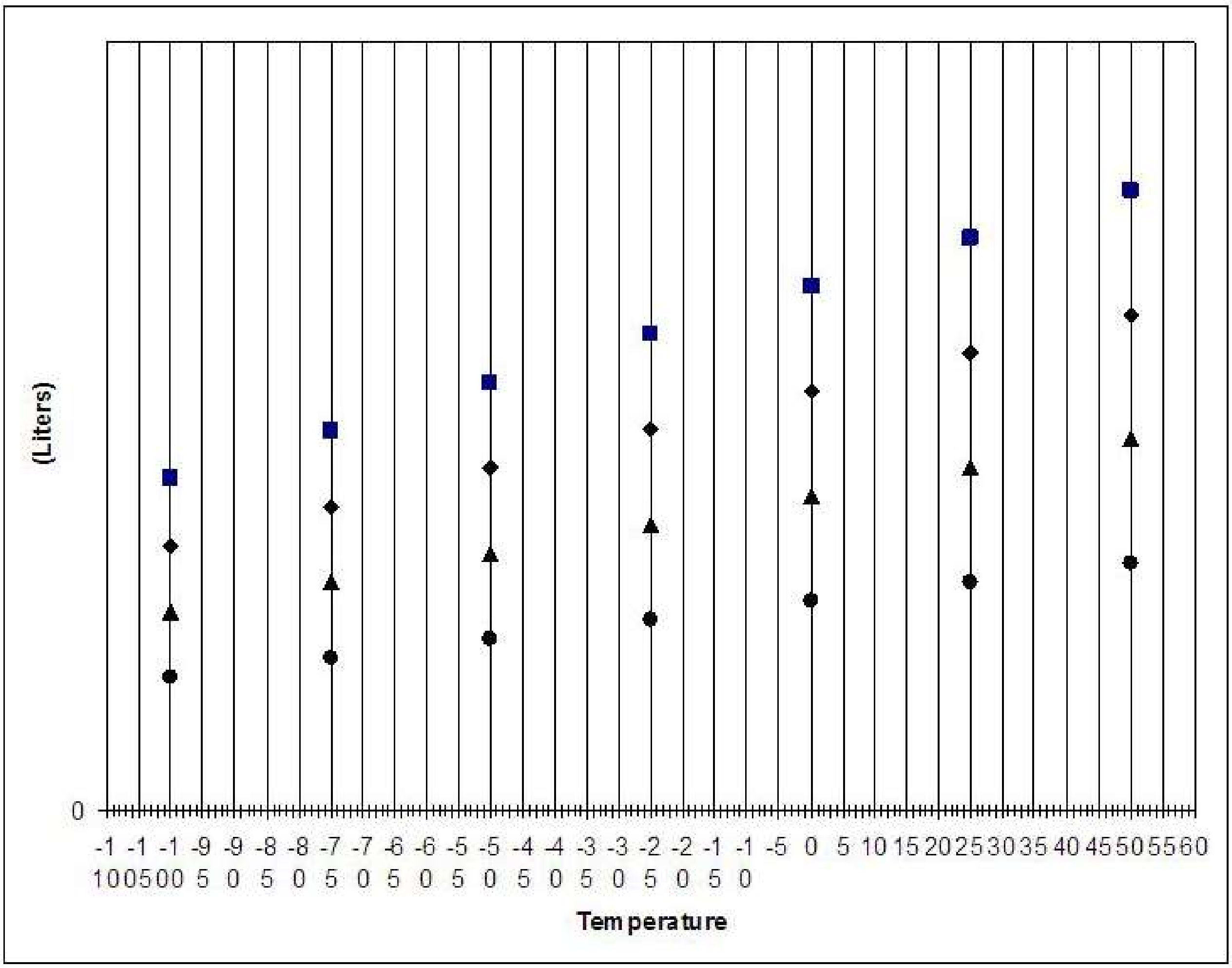

Figure 8.3: An example of a bad graph. credit: author

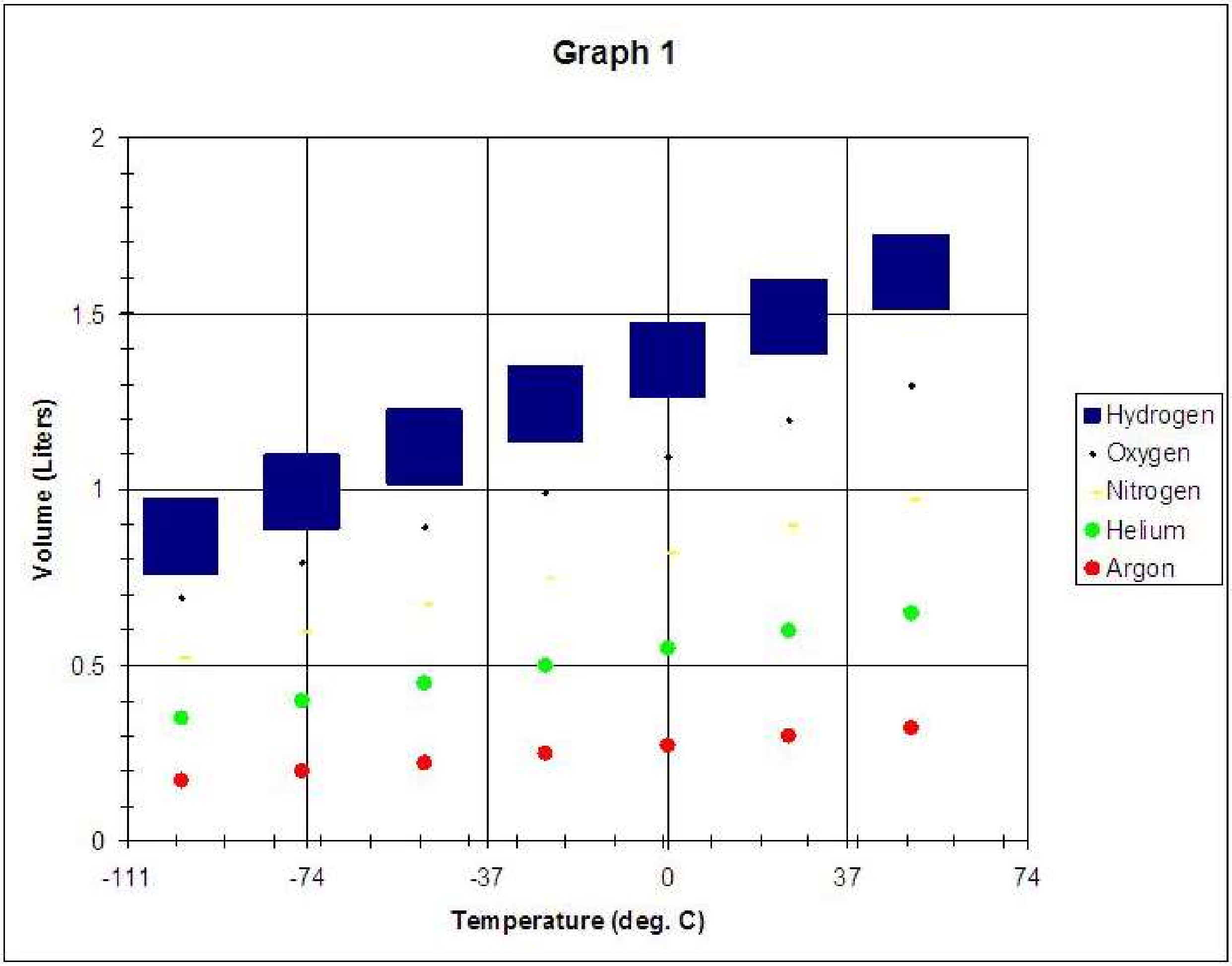

Figure 8.4: Another example of a bad graph. credit: author

Another example of a bad graph is shown in Figure 8.4.

1. Title is not descriptive

2. X axis uses odd spacing and makes no sense. The minor tick marks are not evenly divisible units of the major tick mark.

3. The symbols used for the data points are poor: Series 1 is too big. Series 2 is too small. Series 3 is a hard to see color, (yellow is most often a poor color choice) and the symbol "-" is almost impossible to see on the graph. Series 4 and 5 are the same symbol but different colors. It looks good on the screen but if you print it in black and white you will not be able to tell the difference between the symbols

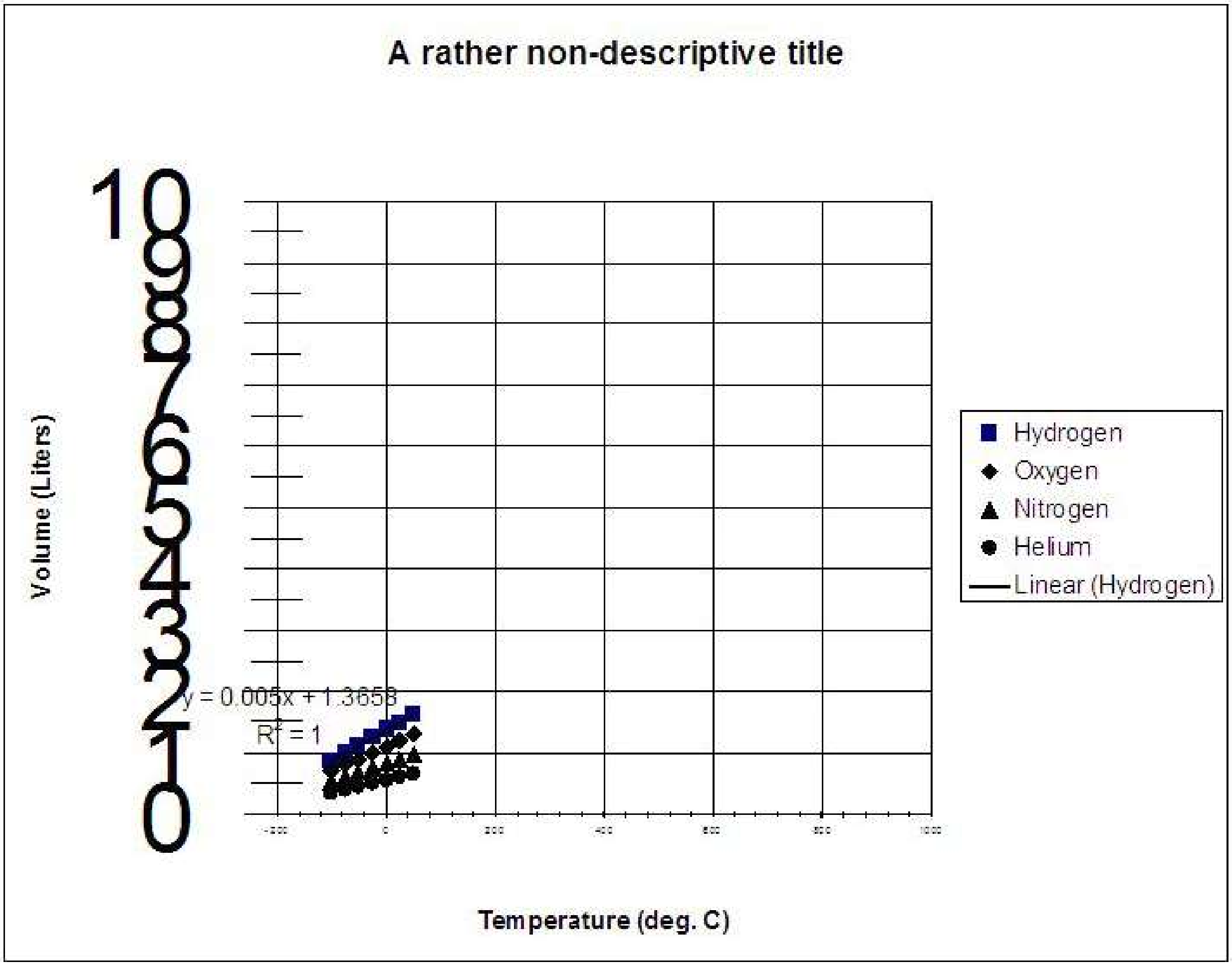

Figure 8.5: Another example of a bad graph. credit: author

One last example of a bad graph is shown in Figure 8.5.

1. The range of the X and Y axis is too large. The data does not span the range selected and ends up in only one small corner of your graph. This leaves a lot of empty unused space which is a waste.
2. The labels for the X axis are too small to read. The font size should be increased.
3. The labels for the Y axis are unnecessarily large and look out of place. The font size should be decreased.
4. The title is rather poor and non-descriptive.
5. The curve fit information overlaps the axis and is hard to read.

C. Graphing with a Computer

Increases in computing power in the last 20 years has lead to the practice of using computers to graph data. This generally speeds up the process. While much of the process is now automated, computers are not yet smarter than humans, and quite often make poor choices. The user needs to make corrections to graphs where needed. In this class we will be using Microsoft Excel to plot our data. It is not the best tool for the job (there are better professional software programs), however, it is sufficient for our purposes and is installed on all campus computers. In the next section we will complete a simple graph using Excel, followed by a general overview of the menu systems for modifying graphs, and some information on how to use the Curve Fitting features of Excel to draw lines through your data points.

D. Problem 1 - Computer Graph 1

Using the following instructions we will now walk through how to make a graph using Excel using the data given below.

Volume (mL)	Pressure (torr)
10.70	250.
7.64	350.
5.57	480.
4.56	600.
3.52	760.
2.97	900.
2.43	1100
2.01	1330

Table 8.1: Data for Practice Computer Graph 1.

Procedure

1. Open the Excel program. In Excel rename the first tab (Sheet 1) to Problem 1. To do this right click on the Sheet 1 tab and choose the rename option. (Figure 8.6a).

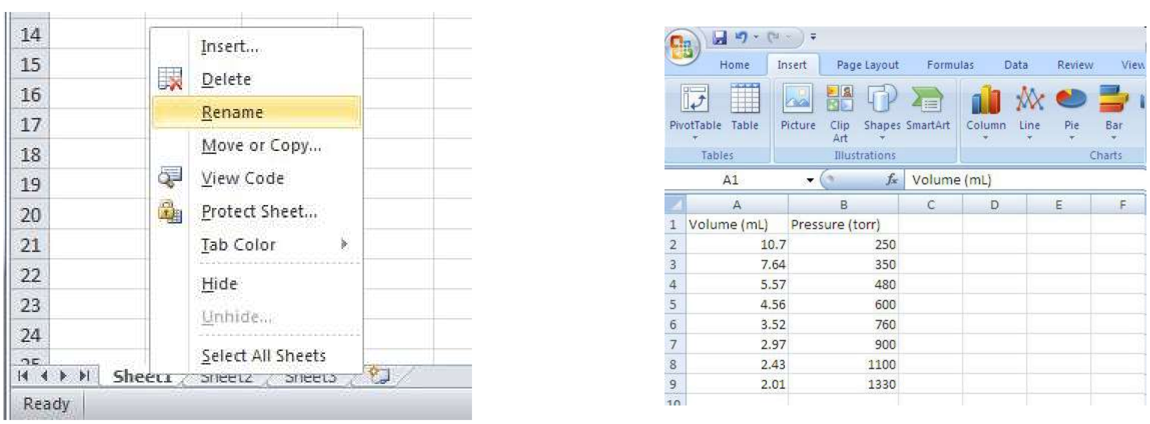

Figure 8.6: (a) Opening Excel (b) Entering data in Excel. credit: author

2. Add the data in Table 8.1 to the sheet. Go to Column A on the new Excel sheet that was opened and in cell A1 type "Volume (mL)" and in B1 type "Pressure (torr)". Adjust the width of the columns

if necessary. Now enter the data shown in the table. When finished entering the data highlight the cells that contain your data, the results should look similar to Figure 8.6.

3. Create a graph by choosing the **Insert** tab and then **Chart** from the ribbon menu. A variety of graph types are available to choose from, we will generally use the XY (Scatter) chart type with the first sub-type shown (default choice).

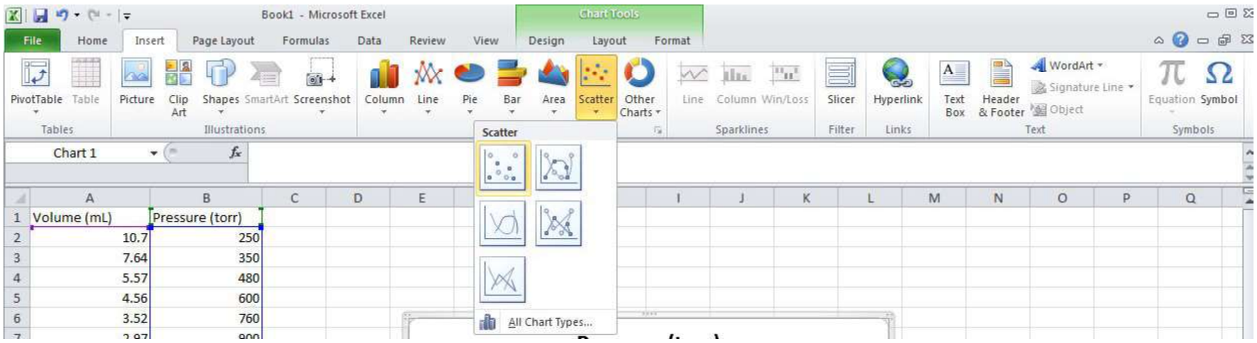

Figure 8.7: Chart Tool - Choose Scatter Plot. credit: author

4. After choosing the scatter plot option, you should be presented with a graph similar to that shown in Figure 8.8. To make the graph easier to work with, you may wish to enlarge the graph by clicking on the corners and dragging.

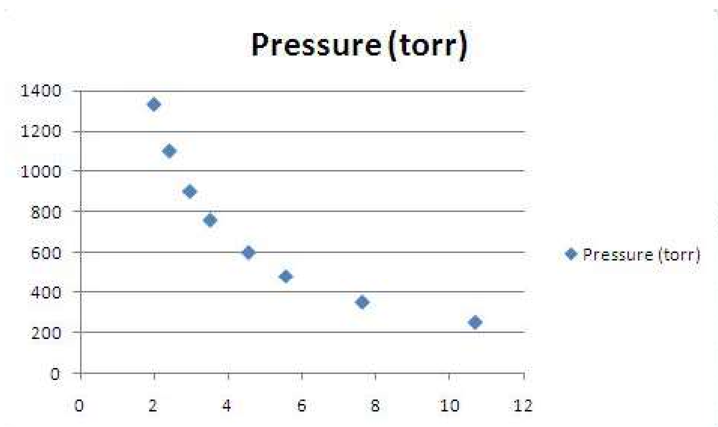

Figure 8.8: Typical Scatter plot generated. credit: author

5. Chart Tools: The current version of Excel uses a tabbed/ribbon menu system has placed many useful tools for formatting your graph in 3 locations as shown below in Figure 8.9 which shows the Layout tools and has the Axis Titles sub menu highlighted.

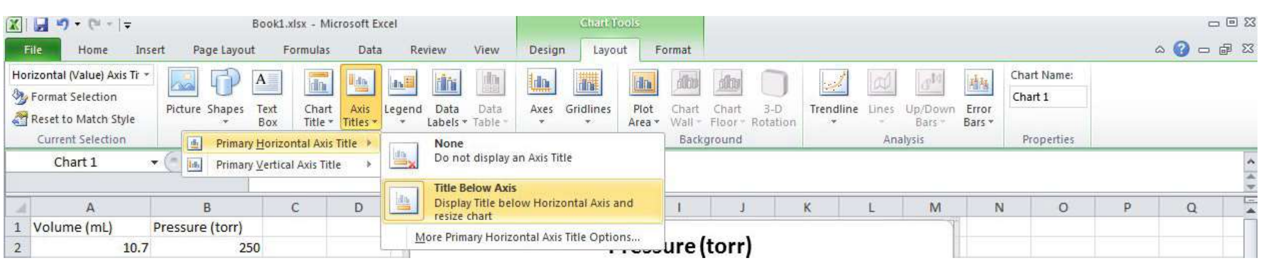

Figure 8.9: Scatter plot with new x and y axis marks. credit: author

(a) Chart Design Tab: This tab contains many options for formatting the data used in the plot, and some layout features such as changing the shape and size of the data points on the graph.

(b) Chart Layout Tab: This tab contains many options for formatting specific features of your chart. You can add/change the Chart Title, Axis Titles, Legends, Data Labels, Grid Lines, Trendlines and many other features.

(c) Chart Format Tab: This tab contains many options for formatting colors and fonts used in your chart. You can change the color, font, shape, alignment and add special effects to your graph.

6. There is no general rule for bringing up menu's in Excel (which is one reason it can be frustrating). In general double clicking on a feature will bring up the default menu, while right clicking (and holding) will bring up a list with many options. To master the use of Excel requires practice and patience.

7. There are several different menu's for changing the major chart options, formatting the axis, formatting data series and many other options. You can access these options by left-clicking on the desired feature and then right-clicking to bring up an options menu for that feature. For example, left-clicking on labels for the y-axis will bring up the format axis menu which allows you to set minimum and maximum values, spacings, tick marks and many other options. (See Figure 8.10.)

   While you are here you may as well change the maximum value on the y-axis to 1600, the minor unit to 50.0, and change the drop down menu for minor tick marks to show inside the graph.

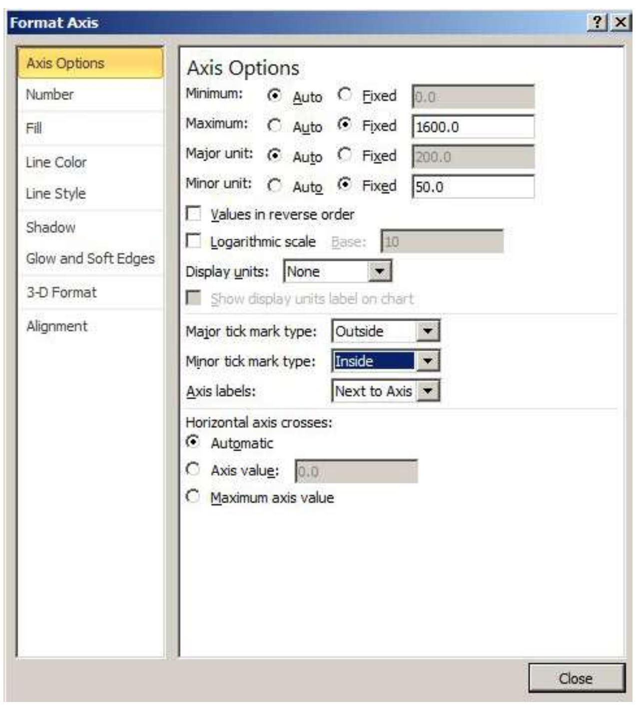

Figure 8.10: The Format Axis Menu. credit: author

8. Now change the x-axis values (using what you have just learned) to label the axis every 2 units with a minor tick mark every 0.5 units. Change the labels on the axis to reflect the precision of your data (to the hundredths). This can be accomplished by changing the number format in your graph from "general" to "number" and choosing to display the numbers to 2 decimal places. The resulting graph should now look similar to what is shown below in Figure 8.11.

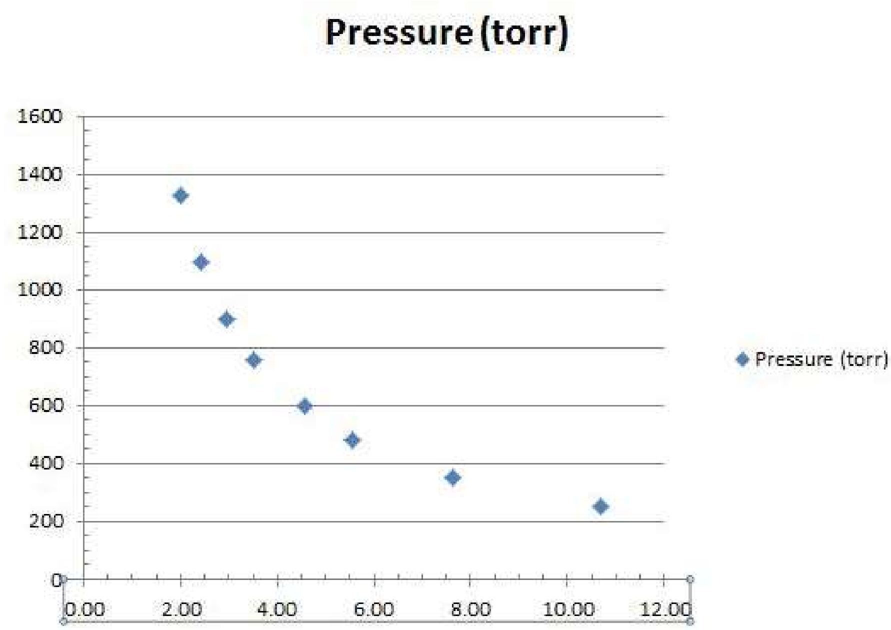

Figure 8.11: Scatter plot with new x and y axis marks. credit author

9. The next several items are some of the more important options you can change. Explore! It is the only way to really learn to properly use Excel to graph data.
10. Change the shape of your data points to be open circles with size = 8.
11. Add Axis titles to your graph. Label the x-axis Volume (mL) and the y-axis Pressure (torr).
12. Add a Chart title to your graph. Name the Graph: Computer Graph 1 - Volume vs. Pressure.
13. Remove the minor and major grid lines.
14. Add a border line around the entire graph.
15. Move the Legend inside the graph (it is a waste of space to leave it outside the graph).
16. Resize your graph to make maximum use of the space on the page.

17. Curve Fitting/Trend Lines: It is often desirable to either draw a line though your data to make it easier to follow separate data sets, or more importantly to fit a mathematical equation to your data in order to extract experimental information. The most common equation to fit to is that of a straight line with the formula $y = mx + b$ where m = slope and b = intercept. It is also useful to print the R^2 value of the equation, because it tells you how good of a curve fit it is, 1 = perfect correlation, 0 = no correlation. An R^2 value greater then 0.95 is generally considered good, anything lower indicates either poor data or the equation used to fit the line is not the correct one.

    (a) Open the **Add Trend line** menu (Figure 8.12) by selecting a data point on the graph and right clicking or chosing the Trendline option on the Chart Tools Layout menu.

    (b) Under the **Type** tab select **Power Series.**

    (c) Under the **Options** tab select the boxes to display the equation on the chart, and to display the R-squared value.

    (d) Move the equation and R-squared value to nice location that does not overlap anything.

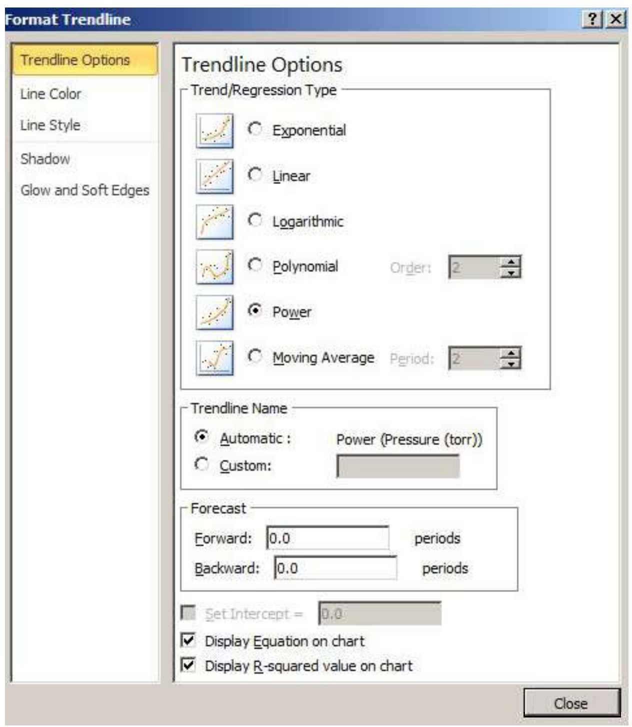

Figure 8.12: Adding a curve fit (trend line). credit: author

18. Add your name and date to the upper right hand corner of your graph. You can use the **Insert tab or the Chart Tools Layout tab** which are selectable from the top menu. Select the **Add Text box** option.

19. Take one last look at your graph. It should look similar to the one shown in Figure 8.13. Are there any more changes you need to make? If so make them.

20. You should be done with your graph now. Show it to your instructor, and print a copy to be turned in with this lab.

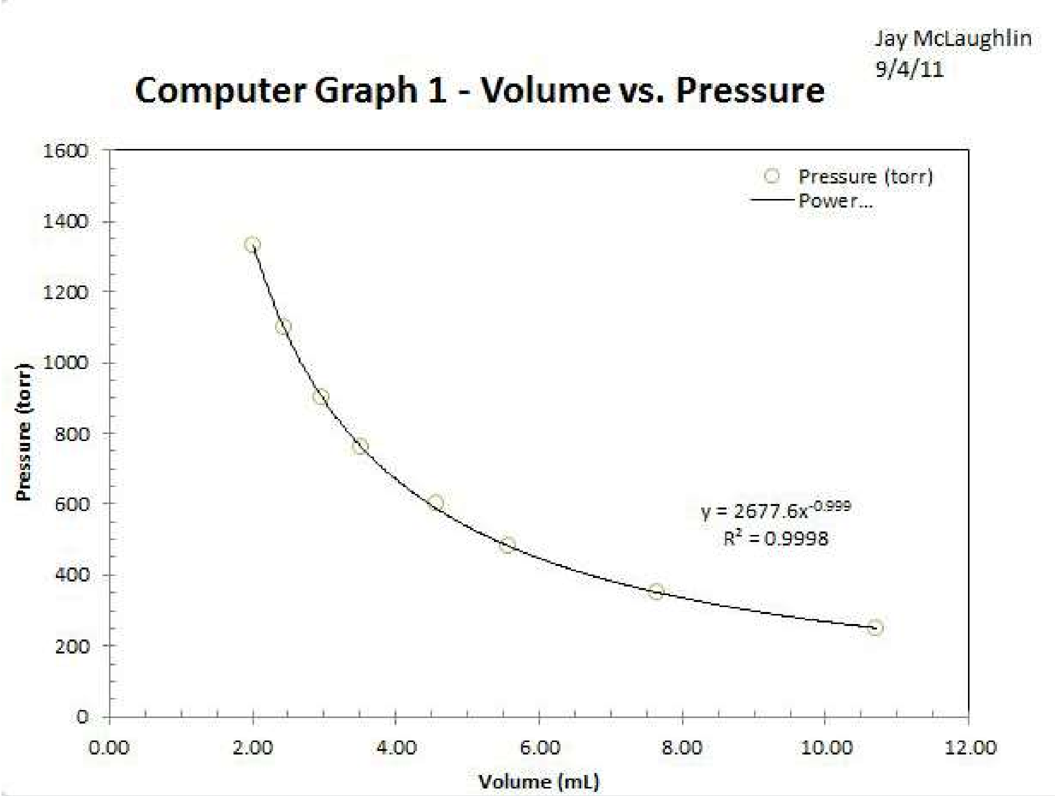

Figure 8.13: Completed computer graph. credit: author

E. Problem 2: Computer Graph 2

Using data provided in Table 8.2 you will make a graph following the instructions below. The data shows the temperature effect on the solubility (how many grams will dissolve in 100. g of water) of four salts. The temperature (x-axis) is measured in ℃ and the solubility (y-axis)in grams substance/100 g water.

1. Type the data set into Excel.
2. The degree symbol for ℃ is found on the top tab under **Insert** than the **Symbols** menu. Scroll to the top and click down three rows, it is located on the right side.
3. Using the mouse highlight the entire data set.
4. Choose the XY (scatter) plot and Click Next.
5. Click the Grid lines tab and add vertical grid lines. Click Next.

Now its time to make the graph look better. Make the following changes to your graph:

1. Change scales on axis. You may need to turn off the "auto" feature in Excel in order to set specific values.
   (a) Change the scale on the X axis to go from 0 to 100 with labels every 10 ℃. Add minor tick marks every 5 ℃.

Temperature (℃)	KCl (g)	NaCl (g)	KBr (g)	$BaCl_2$ (g)
0.0	27.6	35.7	53.5	31.6
10.	31.0	35.8	59.5	33.3
20.	34.0	36.0	65.2	35.7
30.	37.0	36.3	70.6	38.2
40.	40.0	36.6	75.5	40.7
50.	42.6	37.0	80.2	43.6
60.	45.5	37.3	85.5	46.6
70.	48.3	37.8	90.0	49.4
80.	51.1	38.4	95.0	52.6
90.	54.0	39.0	99.2	55.7
100.	55.6	39.8	104	58.8

Table 8.2: Data for Problem 4

(b) Change the scale on the Y axis to go from 0 to 110 with labels every 10 grams and minor tick marks every 2 grams.

2. Remove the grid lines in the X and Y directions. (Hold Right Click choose Chart Options - Grid lines tab)

3. Add a border to your graph. (Hold Right Click choose Format Plot Area).

4. Change the data symbols to all be black and white and size 8. Change the shape so that □ = KCl, ◯ = NaCl , △ = KBr and •= $BaCl_2$.

5. Use the **Insert Tools** tab and then **shapes** draw an arrow pointing to the solubility of NaCl at 20 ℃ and use the Text Box tool to add a text at the end of the arrow saying "Solubility of NaCl at 20 ℃".

6. Curve Fitting: Right click on the KBr data and choose the "Add Trend line" option. Under the "Type" tab choose Linear. Under the "Options" tab click the check box's for Display Equation and Display R Value. Draw an arrow from the equation to the trend line.

7. Move the Legend to inside your graph in the lower right hand corner. Now drag your graph so it takes up most of the space in the graphing window. You always want to maximize the size of your graph so that it is easy to see and read your data.

8. Compare this graph to your first graph and make any changes required to make it a "good" graph.

F. Problem 3 Computer Graph 3

Using the data in the Table 8.3 make a presentable graph from the data. The data you have been given is experimental data for the Vapor Pressure of Water at Various Temperatures. The temperature is given in ℃ and the vapor pressure is measured in torr. Make sure you add a trend line to the graph using a 3rd order polynomial and make sure to include the equation and the R^2 value on the graph.

When you are done making your graph, email your instructor your Excel file with your name in it to `jay.mclaughlin@cncc.edu`. If you don't want to email a copy you may print a copy to hand in to your instructor.

Temperature (℃)	**Vapor Pressure (torr)**
0	4.6
5	6.5
10	9.2
15	12.8
16	13.6
17	14.5
18	15.5
19	16.5
20	17.5
21	18.6
22	19.8
23	21.2
24	22.4
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8
40	55.3
50	92.5
60	149.4
70	233.7
80	355.7
90	525.8
100	760.0
110	1074.6

Table 8.3: Data for Problem 5