

Activity

Graphical Analysis with Excel and Logger Pro

Purpose

Vernier's Logger Pro is a graphical analysis software that will allow you to collect, graph and manipulate data. Microsoft's Excel is a spreadsheet program that allows you to analyze and graph data. This lab will give you some practice using these programs, especially since you will need to graph data many times in your chemistry courses.

Part 1: Dependent and Independent Variables

Sample data below show how the mass changes with volume of an unknown metal.

Table 1. Volume and mass measurements of an unknown metal

Volume (mL)	Mass (g)
2.00	5.100
3.10	8.900
4.00	10.900
5.30	13.800

Here, the volume is displayed as the independent variable (assigned x-values) since the volume was manipulated approximately every 1 mL (specific volumes were *selected* for measurement of the corresponding masses). The mass is the dependent variable (assigned y-values) since mass was recorded in response to the change in volumes.

Part 2: Linear Regression and The Equation of a Line

Linear regression analyzes how well two variables are related to each other by fitting a linear equation to the data.

If there is a linear relationship between volume and mass, a graph will show that the data points look like they connect in a straight line (or nearly so).

You can draw a straight line through the data, not by connecting the points, but by approximating a line that passes as near to as many of the points as possible. This is called a "best-fit" line. The line doesn't necessarily pass through any of the plotted points but it allows you to visualize the "scatter" in the data.

The equation of any straight line is:

$$y = mx + b \quad (1)$$

Where y is the y-axis, x is the x-axis, *m* is the slope and b is the y-intercept (where the line crosses the y-axis).

According to Table 1, you will graph grams as y and milliliters as x, so that Equation 1 above becomes

$$g = m * mL \quad (2)$$

Rearranging Equation 2 gives us the meaning of the slope:

$$m = g/mL \quad (3)$$


(slope, *m*, equals density given in g/mL)

In this case, the slope has a physical meaning. We can use the value of the slope as the density of the metal (Equation 3) which will allow us to identify it later by comparing it with known values of the densities of various metals.

Instead of drawing in the line by "eye", Excel or Logger Pro can find the best-fit line using a least-squares method (from statistics). The programs are capable of determining the equation of the best-fit line as well as a correlation coefficient (R^2). A correlation coefficient close to a value of 1 indicates that the data can be fit perfectly with a straight line.

Part 3: Graphing in Logger Pro

THE FOLLOWING PROCEDURE IS FOR LOGGER PRO.

1. Open Logger Pro. An empty table and empty graph will be displayed.
2. Enter the data given in Table 1.
3. We don't want the points connected. Click on the graph to select it, then choose the **Options** menu then **Graph Options**. Deselect "connect points" and select "point protectors". While you're here, give the graph a title: *Determining the density of an unknown metal*. Click done.
4. It is important to use significant figures (as shown in Table 1) and to label our axes with units. Right-click on the x-column and select **Column Options** and **Data Set | X**. Use the **Column Definition tab** to type in a name, short name, and units for the X-column. Then select the **Options tab** and under "displayed precision" select decimal places. Select the number of decimal places that should be displayed for your x-values (2 in this case). Click done. Repeat for y-values. When finished, check the table for significant figures. Check the graph for axes labels and correct units.
5. To perform the linear regression analysis, choose the Analyze menu then Linear Fit, or click the short-cut button . A best-fit line will appear with the equation of the best-fit line. Move the box containing the equation and correlation coefficient so that the box does not cover the data points!
6. Resize the axes, if necessary, so that the data points are spread out over the entire graph. You don't want all of the data points bunched up in a small corner!
7. Print a copy of the graph for EACH person in your group. Before you do, choose File>Page Setup>Orientation:Landscape. Click OK. Then click File>Print. Check Print Footer and type in your name. Click OK.

Part 4: Graphing in Excel

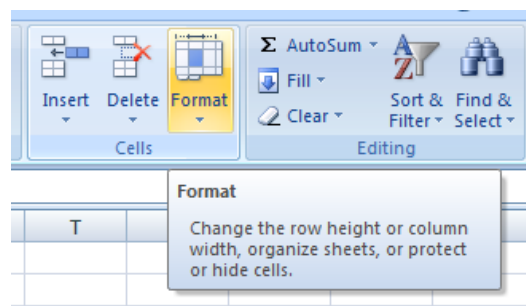
The instructions below for graphing in Excel use the same volume and mass data that you just used in Parts 1-3. Read and follow along with the instructions, but, instead, **graph the temperature data listed here in Table 2**.

Table 2. Temperature readings in units of Celsius and the corresponding measurement in Fahrenheit.

Temperature (°C)	Temperature (°F)
0.0	37.0
10.1	47.0
20.0	71.5
30.2	88.4
40.0	101.2
50.1	125.0

THE FOLLOWING PROCEDURE IS FOR EXCEL2007. (Also ok for Excel 2010.)

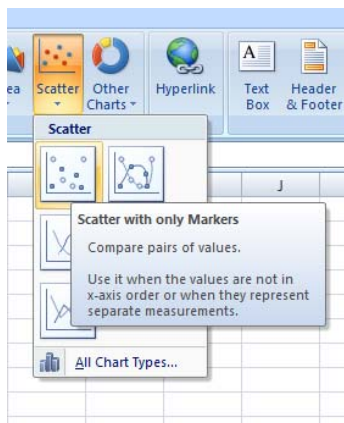
1. Open Excel. Begin column A and B with a heading so that it is clear what **value and units** the numbers in the rest of the column correspond to. For example, in cell A1, type "Volume (mL)". Resize the columns as necessary **Home> Cells> Format> Column Width**.
2. Enter the data given in Table 1.
3. It is important to use significant figures. Highlight the data in column A and in the **Home** menu find **Cells>Format**, click **Format Cells** and in the Number tab select the correct number of decimal places to which the data should be displayed. Use the same number of decimals as in Table 1. Repeat for column B.



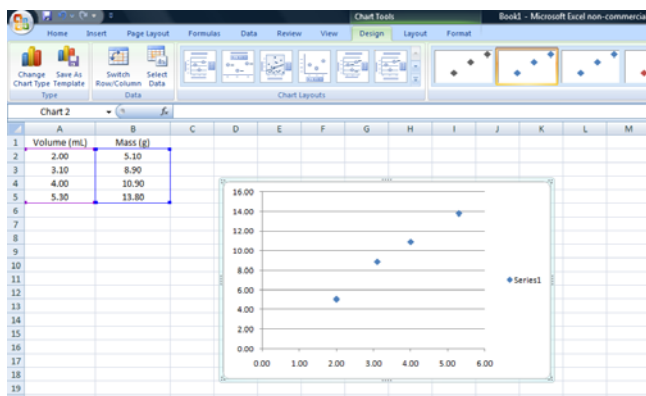
At this point, your spreadsheet should look like this:

	A	B
1	Volume (mL)	Mass (g)
2	2.00	5.10
3	3.10	8.90
4	4.00	10.90
5	5.30	13.80
6		
7		

4. Now you're ready to graph. Select your data by dragging your mouse over it (as it looks above), then click the Insert menu. Choose the **Scatter option** then choose **Scatter with only markers**. You do not want to connect your data points in any way at this point.



Your graph will automatically be embedded in your spreadsheet like so:

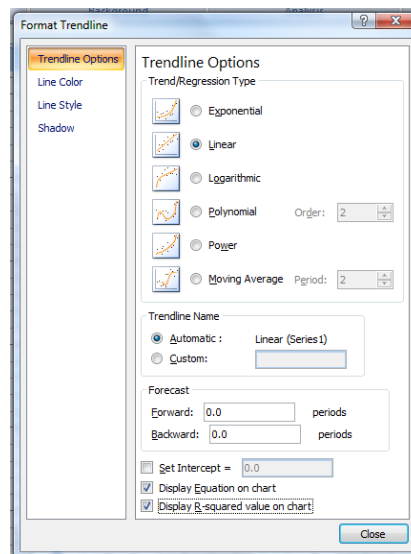


It is best to have your graph as large as possible, so choose the Design>Location>Move Chart option (should be in the top right of your screen). Choose to have the chart as a New Sheet: Chart1. Now your graph is on a whole sheet of paper.

You can change the look of your graph by clicking through **Chart Layouts**. Choose the look that is best appropriate for your graph.

5. It is also important to have a Chart Title and axes labels. For a chart title: Layout>Chart Title. Repeat for axes labels, or if they already appear, click the labels and rename them. Include units!

6. A "best-fit line" averages the data points to approximate a straight line. Right click on one of the data points and all the points should be highlighted automatically. An option will be to **"Add Trendline"**. Select the **linear regression type** and before saying enter, check the last two boxes **"display equation on chart"** and **"display R² value"**. The R² value is a correlation factor (the closer it is to a value of 1, the more the data fits a linear relationship.)



Make sure:

- Your graph is on a full page and has a title and the x- and y-axes are labeled with units;
- The best fit line is displayed with the equation and R² (correlation) value.
- Optional: You can erase the Series box since you only have one series (select and delete). This will make your graph bigger.
- Save your work!
- Print out a copy of your graph. Sign and date your graph. (Do not print extra copies for classmates – they need to make their own unique graph.)

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Activity Turn-in Sheets

Follow-up Questions

Using your density graph prepared using Logger Pro:

1) Using your graph and without doing any calculations, show on the front of your graph how you can estimate the volume for a 4.50-g mass of this unknown metal. (Do this by drawing a line from 4.50-g on the y-axis to the best-fit line, then from that point on the line to the x-axis.)

What is your estimated value for volume? _____ mL

2) What is the equation of the line you obtained? Write it out in the form $y=mx+b$.

What is the correlation factor for the best-fit line shown on your graph? Is this a good correlation?

3) Explain how you can use the information from your graph to estimate the density of the metal.

4) Using the equation displayed on your graph, calculate the volume for a 4.50-g mass of the unknown metal. Show your work below.

5) Use the table below to identify the metal based on the information obtained from your graph. Explain how you chose the metal's identity.

Substance	Density (g/mL)
Magnesium	1.74
Aluminum	2.70
Titanium	4.50
Iron	7.86
Copper	8.93
Gold	19.32

6) How does your metal's density compare to that in the table above? Scientists usually calculate a % error to compare their values with standard values.

$$\% \text{ error} = \left| \frac{\text{experimental} - \text{accepted}}{\text{accepted}} \right| \times 100\%$$

To calculate % error for this lab, use your slope as the experimental value and the density from the chart as the accepted value. Show your work.

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Using your temperature graph prepared using Excel:

6) Looking at the data in Table 2, which appears to be the independent variable, °C or °F?
Explain. On which axis should the independent variable be graphed?

7) What is the equation of the line you obtained? How good is the correlation?

8) The accepted conversion for Fahrenheit to Celsius is given by the following equation:

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32) \quad (4)$$

Rearrange the equation to solve for °F, then compare this with the equation you obtained from the graph. Compare the slope for the rearranged version of Equation 4 to the slope you obtained on your graph. Calculate a percent error.

9) Absolute zero is at -273°C. Use the equation you obtained from your graph to find this value in degrees Fahrenheit.

10) CHALLENGE: There is a temperature that is the same in Celsius as in Fahrenheit. Can you figure it out using Equation 4? Show your work.