# **E1-GRAPHS AND GRAPHING**

In many experiments the data that is collected obeys a physical law that may be expressed mathematically by an equation. If so, graphing the data shows the nature of the equation, and demonstrates **agreement** of the experimental data with the equation.

The graph has another advantage. It shows many experimental observations in a small space, and in an easily understood picture format. If the data obey (or nearly obey) a law that can be expressed in mathematical form, then the graph shows that form very clearly.

Here, the student prepares three graphs in Excel and then uses the graphs to solve problems.

## **VARIABLES, CONSTANTS, AND FUNCTIONS**

A quantity that may have many values is called a **variable**. A quantity that has a fixed value is called a **constant**. When the value of one variable (y) depends on the value of another (x), then y is a **function** of x, or **y = f(x)**. Given a value for x, the value of y is fixed by the relationship between them. For this reason, x is called the **independent** variable, and y is called the **dependent** variable. It is often possible to write an equation that connects the two variables. There are many kinds of equations, or functional relationships.

## **DIRECT FUNCTIONS: THE STRAIGHT LINE**

If a graph of the values of x and y is a straight line, the relationship is said to be linear. The equation of a straight line is:

**y = ax + b**

We take the y axis as the vertical axis (ordinate), and the x axis as the horizontal axis (abscissa). The quantity "a" is a constant, the **slope** of the line. The slope is the ratio of the change in y (Δy) to the change in x ( Δx) and can be computed from the coordinates of any two points on the graph. Thus:

where x1, y1 are the coordinates of one point and x2, y2 are the coordinates of another. The quantity b, another constant, is the y intercept (the value of y when x = 0).

Figure 1 gives the graph of Celsius temperature against Fahrenheit temperature. Of course, these are simply temperature **scales**, and they are related by a simple equation or function. However, there can be experimental data for this relationship if one has a thermometer with one mercury column but two scales, one on either side of the mercury. Then one can take the temperature of some material and write it down in both scales of measurement as shown in Table 1. The relationship between the scales can be expressed by an equation.

**Table 1** Temperatures of a Material in Fahrenheit and Celsius Scales.

| Temperature, oF | Temperature, oC |
| --- | --- |
| -20.0 | -28.9 |
| -100.0 | -73.3 |
| 20.0 | -6.7 |
| 100.0 | 37.8 |
| 240.0 | 115.6 |

Excel graph about Celsius and Fahrenheit temperature scales.


**Figure 1**: Celsius Temperature vs. Fahrenheit Temperature

## **Exercise 1. Temperature Scales**

1. Create a graph in Excel by plotting Celsius temperature against Fahrenheit temperature. Use the points given in Table 1, and any additional points, if you wish. Your instructor will give guidelines for plotting graphs. However, in general, you do the following:

* Spread the data over the axes so that as much of the graph space as possible is used.
* There is no need for the axes to go to zero if the data are far from zero, as shown in Figures 1 and 2.
* Label the axes with the names of the parameter and the units.
* Place a title at the top of the graph.

1. Write the equation of the line in terms of °C and °F.

1. What is the slope of the line including the **unit**?
2. Read the value of the x and y intercepts from the graph. Report these values with **units!** Notice that in this graph, the origin (0,0) of the graph is **NOT** at the lower left corner of the page, because both x and y may have negative values.
3. What Celsius scale is equivalent to 212°F (read from the graph)? Check your equation by using it to calculate the Celsius equivalent of 212°F.

## **INVERSE FUNCTIONS: THE HYPERBOLA**

Figure 2, on the next page, gives the graph of the density of oxygen gas against the temperature of the gas using data shown in Table 2. Notice that as temperature **increases,** density **decreases**;a function of this kind is called **inverse.** If the relationship between y and x is **inverse**, y is proportional to 1/x, and the graph of y vs. x is a **hyperbola**. The equation is

xy = k, or

y = k(1/x)

Here k is a constant, often called a **proportionality** constant. If experimental data are plotted, a curve that tapers off at the axes should result (see Figure 2). An inverse plot can be used to test for a hyperbola. If y is plotted against 1/x, and the resulting graph is a straight line and the y-intercept is zero, then we can conclude that xy = k.

**Table 2** The Change of Oxygen Gas Density with Temperature.

| Density, g/L | Temperature, K | 1/T, K-1 |
| --- | --- | --- |
| 2.8 | 137 | 0.00730 |
| 1.4 | 273 | 0.00366 |
| 0.94 | 405 | 0.00247 |
| 0.70 | 548 | 0.00182 |

Excel graph about density of oxygen gas on various temperatures.

**Figure 2** Density of Oxygen with Temperature

Notice that we can't connect the points by straight lines, but must draw the best curve we can through the data points.

## **Exercise 2. Density and Temperature**

1. The curve in Figure 2 suggests a hyperbola. Test this by making the following graph: plot density of oxygen gas on the y axis and 1/T (K–1) on the x axis.
2. Determine the slope of the resulting line, complete with the **unit**. This is k, the proportionality constant.
3. Write the equation for the relationship between density and temperature for oxygen, in terms of D and 1/T.

**Exercise 3. Density and Concentration**

Here are data for concentration and density of glucose solutions at 20° C:

| Concentration, % by mass | Density, kg/L |
| --- | --- |
| 1.00 | 1.0038 |
| 2.50 | 1.0095 |
| 3.00 | 1.0115 |
| 4.00 | 1.0154 |
| 5.50 | 1.0212 |
| 7.00 | 1.0272 |
| 9.00 | 1.0352 |

The researcher can fix the concentration. Therefore the “% by mass” is the independent variable (x) and the density is the dependent variable (y).

1. Plot the graph of the data in Excel. Think carefully about the range of the data and the direction on the paper for x and for y. (You want the variable with the wider range of values to be on the longer dimension of the paper. Determine if you need to set Portrait or Landscape orientation for you page.) Let x go to zero so that the y intercept can be read from the graph.
2. Find the slope of the line, with the unit.
3. Write the equation of the line in terms of D and %.
4. From the graph, read the density of a 4.80% glucose solution. Pay attention to significant digits!
5. Use the equation of the line to calculate the % by mass of a glucose solution whose density is 1.0652 kg/L.

## **Lab Report**

Submit your Excel graphs for each of the 3 exercises. Your instructor will advise you whether s/he wishes an electronic upload or a printed copy. For each exercise, also include a sheet with the requested calculations and analysis.

If you are unfamiliar with Excel for data entry, manipulation and analysis (such as graphing), your instructor will give a demonstration of the main features of the program for this and several later Chemistry 101 assignments. There is also a document in the Files to assist you. There are many online training resources (although many are oriented toward business applications rather than our fairly simple uses) and there is a Help function in the program. Each version of Excel has slight differences in the menus and location of features so it can be difficult for the faculty to help except in a general way.