Experiment 1
Graphical Analysis of Experimental Data

Introduction

Scientific experiments are often designed to discover the relationship between two parameters in a system. For example, a scientist may want to know how the rate of a chemical reaction changes with an increase in temperature. In order to measure these changes, experiments are designed so that a gradual change in one parameter (temperature) produces a measurable change in the other parameter (reaction rate). The deliberately changed parameter, in this case temperature, is called the independent variable and the observed or measured parameter, in this case the reaction rate, is called the dependent variable. In a scientific experiment it is important that the independent variable be established as precisely and as accurately as possible so that the measurement of the dependent variable will be reproducible.

The data collected in any experiment is often organized into a table. However, just looking at the numbers in the table may not give the experimenter a clear understanding of the relationship between the system parameters. Graphs, pictorial diagrams of the collected data, are often used to interpret the data, determine trends, and derive mathematical equations that govern the relationship between the parameters of the experimental system.

Several types of graphs are common in scientific experiments. Two-dimensional, straight-line or curved-line graphs are most common because they are the easiest to visualize and easily produce useful mathematical equations governing the relationship between the two chosen parameters. Curved line graphs are frequently converted into straight line graphs by simple mathematical manipulation such as converting one or both parameters into logarithms or recriprocals.

Example

A student was given a task to experimentally determine the mathematical equation for the conversion of temperature units from ^oC into ^oF and then to use the data to estimate the temperature in ^oF corresponding to 35^oC.

For this experiment the student used a glass thermometer calibrated in ^oF and a thermostatted hot water bath with a control dial calibrated in ^oC. Using the control dial, (s)he changed the temperature in the water bath in 20^oC increments. After allowing sufficient time to pass to allow the water bath to equilibrate at each temperature (s)he recorded the temperature of the water in both ^oC and ^oF. The experimental data are recorded in Table 1.

Table 1

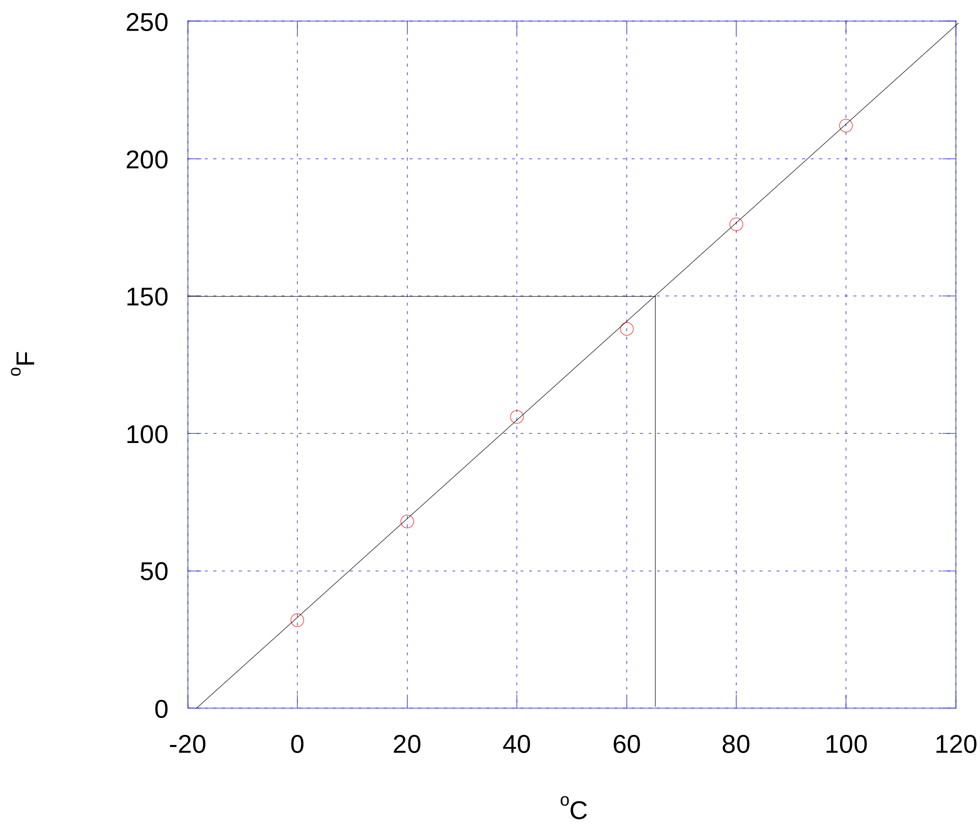
^oC	^oF
20	68
40	106
60	138
80	176
100	212

The student then graphed the measured data with °C as the independent variable and °F as the dependent variable (Figure 1). The general equation for a straight line is

$$y = mx + b \qquad \text{Equation 1}$$

Where x is the independent variable, y is the dependent variable, m is the slope of the straight line and b is the x-intercept, that is, the value of y when x equals zero. In this equation both m and b are constants. If x = 0 is not a data point, b can be extrapolated on the graph by drawing the line back to the point where the line crosses the y axis.

Figure 1. The plot of the student's data with °C as the independent variable and °F as the dependent variable



The graph indicates that there is a linear dependence between the independent variable and the dependent variable. The slope, m, is therefore calculated by dividing the difference between any two widely spread values of y from the experimental line by the difference between the corresponding values of x (Equation 2).

$$\text{Slope} = \Delta y/\Delta x = (y_2 - y_1)/(x_2 - x_1) \qquad \text{Equation 2}$$

It is important when calculating the slope from a graph that the x and y values of the points chosen for the calculation of the slope are from the best fit line and not from the data points. In this way one can avoid errors due to faulty data points. In the example above, using two points from the line, (10, 50) and (92, 200), the slope is calculated.

$$m = (200-50)/(92-10) = 1.8(^oF/^oC) \qquad \text{Equation 3}$$

The x intercept is calculated using any point on the line, for example, (66.5, 150).

$$150^oF = 1.8(66.5^oC) + b, \text{ or } b = 150 - (1.8 \text{ X } 66.5) = 32 \qquad \text{Equation 4}$$

The equation for the temperature conversion is therefore

$$^oF = 1.8(^oC) + 32 \qquad \text{Equation 5}$$

It is important to note that experimental data is often non-linear or that one frequently encounters points that do not fall on the line produced by the rest of the data. In the former case one can mathematically manipulate the data as described above or one can try to fit the line to a second order equation. Such fits are most easily done on a computer using graphing software. In the second case one can take multiple measurements of each point by taking an average or by dropping a single measurement from consideration one can minimize the errors in the measurements.

Oncethe equation of the line is calculated one can calculate any value of y for any given value for x (and vice versa). One can also use interpolation to find the values of any point on the line. To do so, one locates the point on the x axis and draws a line to the experimental line and then a perpendicular line is drawn to the y axis as illustrated in Figure 1 for the interpolation of the point used to calculate the x-intercept.

Chemistry 1215 Experiment 1: Graphical Analysis of Experimental Data, Postlab

Name _________________________

Imagine that you are inflating a round balloon with a pump that delivers 900 mL of gas with each pump. After each pump you measure the diameter of the balloon. The measurements are tabulated below. (A) Draw a graph of the experimental data and correctly label the x and y axes. (B) Determine the equation for the line that relates the number of pumps to the resulting diameter. (C) Graphically determine the diameter of the balloon if 5.5 pumps of air are added to the balloon. **Show all calculations.**

Number of pumps	Balloon Diameter (cm)
1	15
2	17
3	20
4	22
5	23
6	25
7	28
8	32
9	34