Verification of Boyle's Law for a Real Gas

Introduction

Boyle's Law states that pressure and volume are inversely proportional for a sample of gas at constant temperature. Mathematically, this relationship can be expressed

$$PV = k_B \qquad (1)$$

where k_B is a constant. In the strictest sense, Boyle's Law is only truly applicable for an ideal gas: Equation 1 results directly from the Ideal Gas Law, with temperature and moles held constant. In this experiment, we investigate the validity of Boyle's Law for a real gas, air, at normal room temperature conditions.

Experimental

A Matheson Model 1823 Gas-Tight syringe was connected to a Smith PressurePro pressure sensor with about 5 cm of ¼-in Tygon tubing. The pressure sensor was interfaced by a USB connection to a PowerIII:33 laptop computer running Scientific Industries CollectData software. The tubing was connected through a 3-way stopcock which allowed the syringe to be set at any initial volume at atmospheric pressure. From the initial volume point, we moved and held the syringe by hand, reading and recording several pressure-volume ordered pairs. The temperature during data collection was constant at 24.5^{o}C, measured with a VWR laboratory thermometer.

Results and Discussion

We chose 10.0 mL as our initial syringe volume, at which point we recorded a pressure of 0.98 atm. To each of the volume readings, we added 1.15 mL to account for the volume of the connective tubing. We determined the volume of the tubing by filling it with water from a 10-mL graduated cylinder.

Figure 1 shows a graph of the raw data.

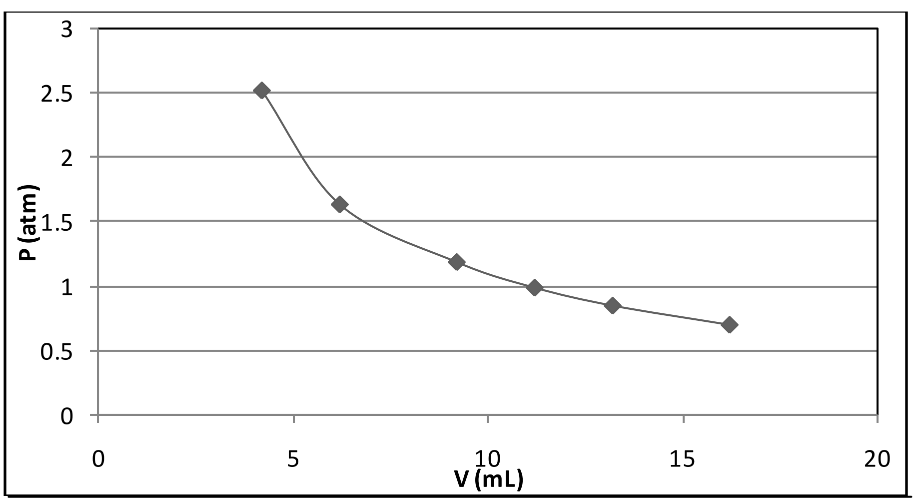

Figure 1: Pressure versus volume for air contained in a syringe

The graph in Figure 1 shows the characteristic shape of a hyperbolic function as described by Equation 1. Nevertheless, Figure 1 does not confirm the data points are obeying Equation 1. Table 1 shows the value of pressure multiplied by volume for each data point. If the data points obey Boyle's Law, we would expect the product of pressure and volume product to be constant.

Table 1: Pressure multiplied by volume for each data point

Data Point	V (mL)	P (atm)	P*V (atm*mL)
1	4.2	2.52	11
2	6.2	1.63	1.0×10^1
3	9.2	1.18	11
4	11.2	0.98	11
5	13.2	0.84	11
6	16.2	0.69	11

The results of Table 1 show clearly, with one minor exception, that the product of pressure and volume is constant within the measurement significant figures. The anomalous point may have resulted from a misreading of the syringe, or from an unsteady hand during the measurement.

As further evidence that the air in the syringe obeys Boyle's Law, we show in Figure 2 a plot of pressure versus inverse volume. Equation 1 can rearranged as follows

$$P = k_B\left(\frac{1}{V}\right) \qquad (2)$$
$$y = m\ x \quad + \quad b$$

Beneath Equation 2 we have shown the general equation for a straight line, for purpose of comparison. By comparing Equation 2 with y = mx +b, we infer that a graph of pressure versus inverse volume for a gas obeying Boyle's Law should show a straight line with slope equal to k_B.

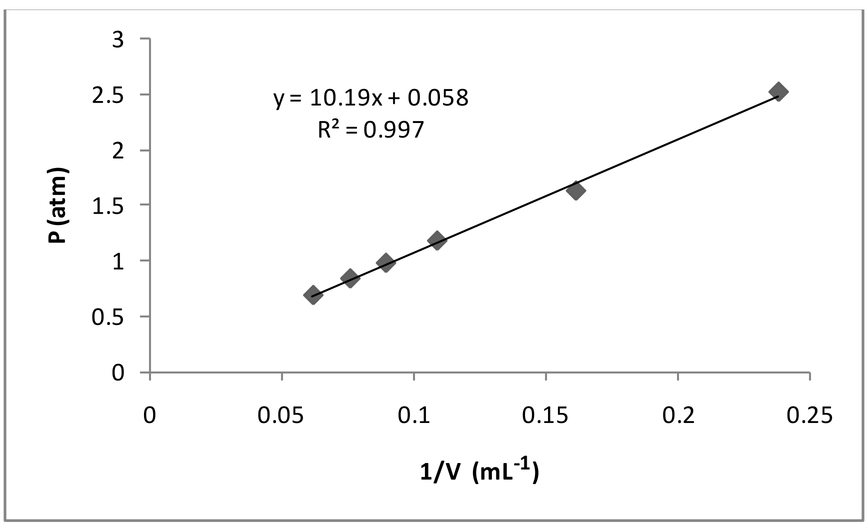

Figure 2: Pressure versus inverse volume for air contained in a syringe

The plot in Figure 2 appears to be linear, and the value of the correlation coefficient (R^2) shows that our data are a good fit to a straight line. There is a slight difference in the k_B value from Table 1, the direct result of pressure times volume, and the k_B value from the slope of the line in Figure 2. The k_B value in Figure 2 may be the more reliable one, since a straight-line fit with a correlation coefficient close to 1 is statistically valid.

Conclusion

Based on the constant value of the product of pressure and volume and on the linearity of pressure plotted versus inverse volume, our results show that air at room temperature does indeed obey Boyle's Law. Since Boyle's Law is derived from the ideal gas law, for calculations involving air at the normal temperatures and pressures encountered in the laboratory, we can use the Ideal Gas Law with confidence our results will be accurate.

*****Things you should note : *****

1) In the experiment section, I am very specific (i.e. brand and model) about what equipment I am using. If you're using software and hardware, you must state what is hardware and what is software and how they are connected. Common laboratory apparatus (beakers, flasks, etc.) need not be listed specifically unless their use is integral to the experimental procedure. For example, in the above report I explained I used a 10-mL graduated cylinder to measure the tubing volume.
2) In the figures, I include a descriptive caption at the bottom. For tables, the caption is usually shown on top. Note that you will frequently need to include units when showing a table. Also note that plots should always have the appropriate units on the axis labels.
3) In plots, it is okay to join the points with a line, as long as the reader can clearly see the data points you collected
4) There is no need to show raw data points in the report unless you are going to discuss a specific portion of the data. In this report, I showed raw data because I wanted to relate it directly to the calculation of P*V, so the reader could see where I was getting the P*V values.
5) Section headings are set off in **Bold**
6) Temperature are shown as "^{o}C", not "degrees Celsius".
7) In a short lab report, abstracts are usually not necessary. When you write long reports, an abstract is helpful to give the reader a general idea of what the report says
8) If you are investigating a specific hypothesis, the Introduction is where you would state the hypothesis.
9) Equations are labeled with a number, in parentheses, on the far right of the document. When you need to refer to the equation, you can then refer to it by number.