Chemistry:
Boyle's Law: Pressure-Volume Relationship in Gases

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas. The gas we use will be air, and it will be confined in a syringe connected to a pressure sensor (see Figure 1). When the volume of the syringe is changed by moving the piston, a change in the pressure exerted by the confined gas results. This pressure change will be monitored using a pressure sensor interfaced to a computer. It is assumed that temperature will be constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. From the data and graph, you should be able to determine what kind of mathematical relationship exists between the pressure and volume of the confined gas. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.

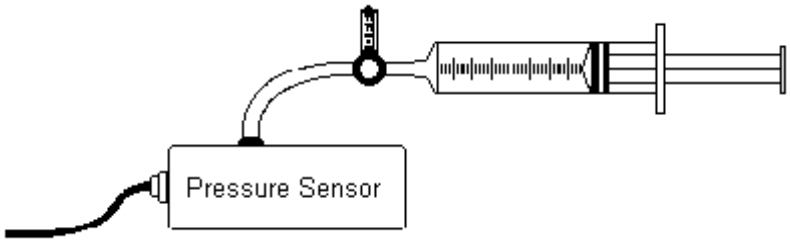


Figure 1

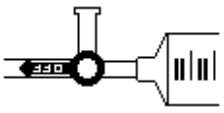
MATERIALS

Macintosh or IBM-compatible computer	Vernier Pressure Sensor
Serial Box Interface or ULI	20-mL gas syringe
Logger *Pro*	

PROCEDURE

1. Prepare the Pressure Sensor and an air sample for data collection.
   Plug the Pressure Sensor into Port 1 of a Serial Box Interface or ULI that is connected to a computer.
   Open the side arm of the pressure sensor valve to allow air to enter and exit.
   Open its side valve by aligning the blue handle with the arm that leads to the pressure sensor as shown in Figure 2.

- Move the piston of the syringe until the front edge of the inside black ring (indicated by the arrow in Figure 3 on the next page) is positioned at the 10.0 mL mark.



- Close the side arm of the pressure sensor valve by aligning the blue handle with the side arm (see Figure 3).

Figure 2

2. Prepare the computer for data collection by opening "Exp 06" from the *Chemistry with Computers* experiment files of Logger *Pro*. The vertical

axis has pressure scaled from 0 to 2.5 atm. The horizontal axis has volume scaled from 0 to 20 mL.

3. Click Collect to begin data collection.

4. Collect the pressure vs. volume data. It is best for one person to take care of the gas syringe and for another to operate the computer.

- Move the piston to position the front edge of the inside black ring (see Figure 3) at the 5.0-mL line on the syringe. Hold the piston firmly in this position until the pressure value stabilizes.
- When the pressure reading has stabilized, click Keep. Type "5.0" in the edit box. Press the ENTER key to keep this data pair. Note: You can choose to redo a point by pressing the ESC key (after clicking Keep, but before entering a value).

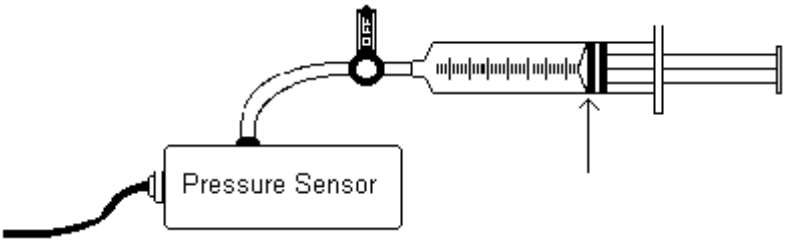


Figure 3

5. Repeat the Step 4 procedure for volumes of 7.5, 10.0, 12.5, 15.0, 17.5, and 20.0 mL.

6. Click Stop when you have finished collecting data. In your data table, record the pressure and volume data pairs displayed in the Table window (or, if directed by your instructor, print a copy of the Table window).

7. Examine the graph of pressure vs. volume. Based on this graph, decide what kind of mathematical relationship you think exists between these two variables, direct or inverse. To see if you made the right choice:

- Click the Curve Fit button, .
- Choose Variable Power (y = Ax^n) from the list at the lower left. Enter the value of *n* in the Degree/Exponent edit box that represents the relationship shown in the graph (e.g., type "1" if direct, "-1" if inverse). Click Try Fit.
- A best-fit curve will be displayed on the graph. If you made the correct choice, the curve should match up well with the points. If the curve does not match up well, try a different exponent and click Try Fit again. When the curve has a good fit with the data points, then click OK.

8. Once you have confirmed that the graph represents either a direct or inverse relationship, print a copy of the Graph window, with the graph of pressure vs. volume and its best-fit curve displayed. Enter your name(s) and

the number of copies you want to print.

DATA AND CALCULATIONS

Volume (mL)	Pressure (atm)	Constant k (P/V or P*V)

PROCESSING THE DATA

1. If the volume is *doubled* from 5.0 mL to 10.0 mL, what does your data show happens to the pressure? Show the pressure values in your answer.
2. If the volume is *halved* from 20.0 mL to 10.0 mL, what does your data show happens to the pressure? Show the pressure values in your answer.
3. If the volume is *tripled* from 5.0 mL to 15.0 mL, what does your data show happened to the pressure? Show the pressure values in your answer.
4. From your answers to the first three questions *and* the shape of the curve in the plot of pressure versus volume, do you think the relationship between the pressure and volume of a confined gas is direct or inverse? Explain your answer.
5. Based on your data, what would you expect the pressure to be if the volume of the syringe was increased to 40.0 mL? Explain or show work to support your answer.
6. Based on your data, what would you expect the pressure to be if the volume of the syringe was decreased to 2.5 mL? Explain or show work to support your answer.
7. What experimental factors are assumed to be constant in this experiment?
8. One way to determine if a relationship is inverse or direct is to find a proportionality constant, k, from the data. If this relationship is direct, k = P/V. If it is inverse, k = P•V. Based on your answer to Question 4, choose one of these formulas and calculate k for the seven ordered pairs in your data table (divide or multiply the P and V values). Show the answers in the third column of the Data and Calculations table.
9. How *constant* were the values for k you obtained in Question 8? Good data may show some minor variation, but the values for k should be relatively constant.
10. Using P, V, and k, write an equation representing Boyle's law. Write a verbal statement that correctly expresses Boyle's law.

EXTENSION

1. To confirm the type of relationship that exists between pressure and volume, a graph of pressure versus the *reciprocal of volume* (1/volume or volume-1) may also be plotted. To do this using Logger *Pro*, it is necessary to create a new column of data, reciprocal of volume, based on your original volume data.
   - Remove the Linear Regression box from the graph by clicking on its upper-right corner.
   - Choose New Column ▸ Formula from the Data menu.
   - Enter "1/Volume" as the Long Name, "1/V" as the Short Name, and "1/mL" as the Unit. Then click on the Definition tab.
   - Enter the correct formula for the column (1/volume) into the Equation edit box. To do this, type in "1" and "/". Then select "Volume" from the Variables list. In the Equation edit box, you should now see displayed: 1/"Volume". Click OK.
   - Click on the vertical-axis label, select "Pressure" (only), and click OK. Click on the horizontal-axis label, select "1/Volume" to be displayed on the horizontal axis, and click OK.

2. Decide if the new relationship is direct or inverse and change the formula in the Fit menu accordingly.
   - Click the Curve Fit button,  .
   - Choose Variable Power (y = Ax^n) from the list at the lower left. Enter the value of *n* in the exponent edit box that represents the relationship shown in the graph (e.g., type "1" if direct, "-1" if inverse). Click Try Fit.
   - A best-fit curve will be displayed on the graph. If you made the correct choice, the curve should match up well with the points. If the curve does not match up well, try a different exponent and click Try Fit again. When the curve has a good fit with the data points, then click OK.

3. If the relationship between P and V is an inverse relationship, the plot of P vs. 1/V should be direct; that is, the curve should be linear and pass through (or near) your data points. Examine your graph to see if this is true for your data.

4. (Optional) Print a copy of the Graph window. Enter your name(s) and the number of copies of the graph you want, then click OK.