Gas Pressure and Volume

In this simple experiment, you will use a computer-interfaced Pressure Sensor and a gas syringe to study the relationship between gas pressure and volume. Temperature and amount of gas will be kept constant. The results will be expressed in words, in a table, with a graph, and with a mathematical equation. These are four methods commonly used by scientists to communicate information.

This experiment is similar to one first done by Robert Boyle in 1662—without the use of a computer, of course. The relationship you will discover is known as Boyle's law.

OBJECTIVES

In this experiment, you will

- use a computer-interfaced Pressure Sensor and a gas syringe to measure the pressure of an air sample at several different volumes
- make a table of the results
- graph the results
- predict the pressure at other volumes
- describe the relationship between gas pressure and volume with words and with a mathematical equation

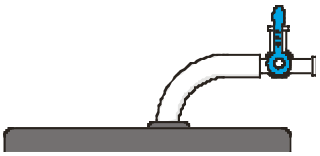
MATERIALS

Power Macintosh or Windows PC
Vernier computer interface
Logger*Pro*
Vernier Pressure Sensor with 20-mL gas syringe

Figure 1

PROCEDURE

1. Prepare the Pressure Sensor and an air sample for data collection.
   a. Plug the Pressure Sensor into Channel 1 of the computer interface.
   b. With the 20-mL syringe disconnected from the Pressure Sensor, move the piston of the syringe until the front edge of the inside black ring (indicated by the arrow in Figure 1) is positioned at the 10.0 mL mark.
   c. Attach the 20-mL syringe to the valve of the Pressure.
      • Newer Vernier Gas Pressure Sensors have a white stem protruding from the end of the sensor box—attach the syringe directly to the white stem with a gentle half-turn.
      • Older Vernier Pressure Sensors have a 3-way valve at the end of a plastic tube leading from the sensor box. Before attaching the 20-mL syringe, align the blue handle with the stem of the 3-way valve that will *not* have the syringe connected to it, as shown in the figure at the right—this will close this stem. Then attach the syringe directly to the remaining open stem of the 3-way valve.



2. Prepare the computer for data collection.
   • Prepare the computer for data collection by opening the Experiment 30 folder from *Physical Science with Computers*. Then open the experiment file that matches the sensor you are using.
   • On the Graph window, the vertical axis has pressure scaled from 0 to 250 kPa. 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.
   a. 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.

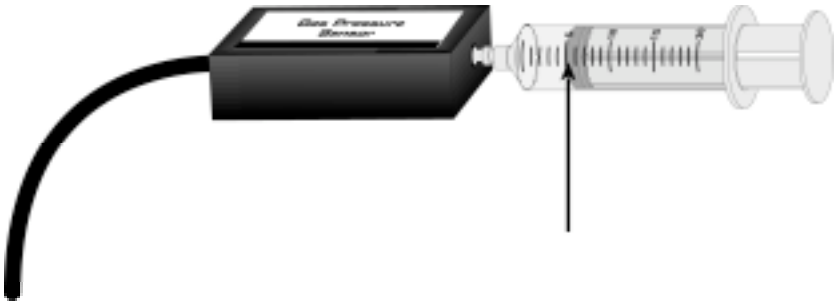


Figure 3

   b. 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).
   c. Continue the procedure for volumes of 7.5, 10.0, 12.5, 15.0, 17.5, and 20.0 mL.
   d. Click Stop when you have finished collecting data.
5. 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).

6. 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:
   a. Click the Curve Fit button,  .
   b. 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.
   c. 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.

7. 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

Volume (mL)	5.0	7.5	10.0	12.5	15.0	17.5	20.0
Pressure (kPa)	_____	_____	_____	_____	_____	_____	_____

PROCESSING THE DATA

1. See the data table and note the pressure when the volume is 10.0 mL, and when the volume is 5.0 mL. What happened to pressure when the volume was halved?

2. See the data table and note the pressure when the volume is 20.0 mL. Compare this pressure to the pressure when the volume is 10.0 mL. What happened to the pressure when the volume was doubled?

3. From your graph, what is the pressure when the volume is 16 mL? 8 mL? How do these values compare?

4. What would the pressure be at 40.0 mL? At 2.5 mL? Explain how you determined these values.

5. What is the relationship between gas pressure and volume (Boyle's law) in words?

6. Do gas pressure and volume vary directly or inversely? Explain.

7. Write an equation to express the relationship between gas pressure and volume. Use the symbols P, V, and k.

EXTENSIONS

1. To confirm that an inverse relationship 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.
   - 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. 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. In the same way, select "1/Volume" to be displayed on the horizontal axis, and click OK.

Make a best-fit curve.

- Choose Graph Options on the View menu.
- Uncheck Connecting Line on the Graph Options list.
- Click OK.
- Click the Curve Fit button,  .
- Choose Variable Power (y = Ax^n) from the list at the lower left. Type "1" in the exponent edit box. Click Try Fit.
- Click OK.

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.

(optional) Print the graph of P vs. 1/V.

2. Repeat the experiment using a pure, noncorrosive gas, such as oxygen, butane, or carbon dioxide. Compare the results with your results for air.