

BOYLE'S LAW: PRESSURE-VOLUME RELATIONSHIP IN GASES

LAB PS 1.COMP

From *Chemistry with Computers*, Vernier Software & Technology, 2000

INTRODUCTION

Gas molecules are all around us. They surround us in the atmosphere, which is a mixture containing nitrogen and oxygen molecules as its two major components. We also encounter helium in balloons that float and carbon dioxide in the bubbles that escape from our carbonated beverage. You can think of many other gases in that play important roles in our lives.

Chemists study gases to help us understand our world. Gases differ from liquids and solids because their molecules move freely to fill any volume. To describe the physical properties of a gas, chemists define four values: the **quantity** of the gas, the **temperature** of the gas, the **volume** of the gas, and the **pressure** of the gas.

This experiment will show 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 occurs in the pressure exerted by the confined gas. This pressure change will be monitored using a Pressure Sensor. It is assumed that temperature will be constant, as is the quantity of gas, 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.

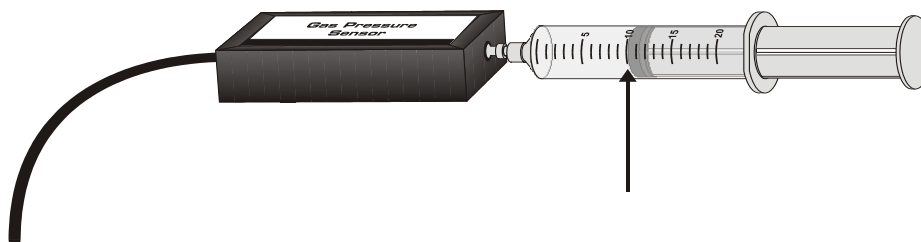


Figure 1

PURPOSE

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas.

SAFETY





- Always wear goggles and an apron in the lab.

MATERIALS

Laptop computer
LabPro
LoggerPro

Vernier Gas Pressure Sensor
20-mL gas syringe
Computer-Labpro interface cable

PROCEDURE

1. Prepare the Pressure Sensor and an air sample for data collection.
 - a. Plug the Pressure Sensor into Channel 1 (CH1) of the LabPro.
 - 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 white stem protruding from the end of the pressure sensor box with a gentle half-turn.
2. Prepare the computer for data collection.
 - a. Prepare the computer for data collection by opening the Experiment 6 folder from *Chemistry with Computers*. Then open the experiment file, Exp 06 Gas Pressure Sensor.
 - b. 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  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 2) at the 5.0-mL line on the syringe. Hold the piston firmly in this position until the pressure value in the Meter Window stabilizes.
 - b. When the pressure reading has stabilized, click . 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 , 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  when you have finished collecting data.

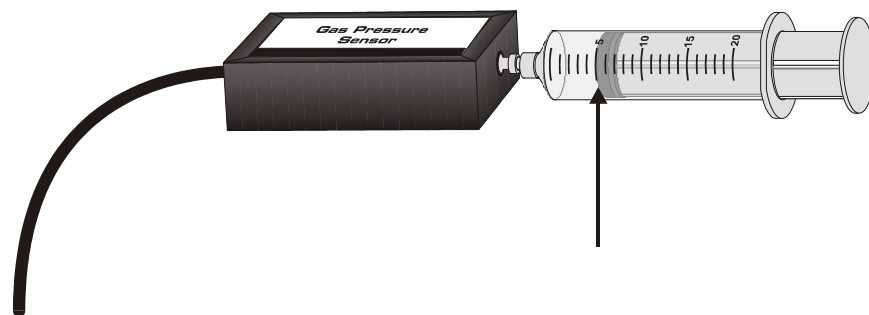






Figure 2

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 .
 - 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  again. When the curve has a good fit with the data points, then click .
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 SHEET

Name _____
Name _____
Period _____ Class _____
Date _____

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DATA TABLE

Volume (mL)	Pressure (kPa)	Constant, k (P/V or P•V)

QUESTIONS

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 curves in the plots of pressure versus volume in direct and inverse relationships, 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, $k = P \cdot V$. 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. Express Boyle's law in one sentence.

EXTENSION

- To confirm the type of relationship that exists between pressure and volume, a graph of pressure versus the *reciprocal of volume* ($1/\text{volume}$ or volume^{-1}) may also be plotted. To do this using *LoggerPro*, 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 ($1/\text{volume}$) 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: $1/\text{Volume}$. Click .
 - Click on the vertical-axis label, select “Pressure” (only), and click . Click on the horizontal-axis label, select “1/Volume” to be displayed on the horizontal axis, and click .
- 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 .
 - 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 again. When the curve has a good fit with the data points, then click .
- 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 a copy of the Graph window. Enter your name(s) and the number of copies of to print.