

Gases Lab #2: Boyle's Law: Pressure-Volume Relationship in Gases; SC6 a,b,c



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 Gas 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 Gas Pressure Sensor. 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.

OBJECTIVES

In this experiment, you will

- Use a Gas Pressure Sensor and a gas syringe to measure the pressure of an air sample at several different volumes.
- Determine the relationship between pressure and volume of the gas.
- Describe the relationship between gas pressure and volume in a mathematical equation.
- Use the results to predict the pressure at other volumes.

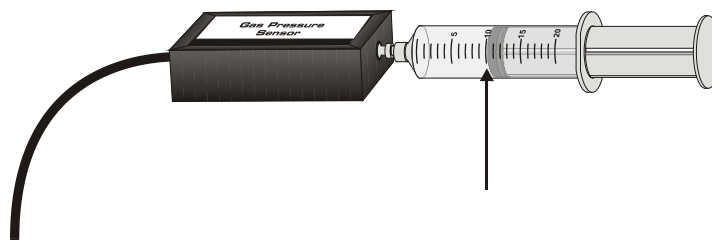


Figure 1

MATERIALS

LabQuest
LabQuest App

Vernier Gas Pressure Sensor
20 mL gas syringe

PROCEDURE

1. Prepare the Gas Pressure Sensor and an air sample for data collection.
 - a. Connect the Gas Pressure Sensor to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.
 - b. With the 20 mL syringe disconnected from the Gas 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 Gas Pressure Sensor.
2. Set up the data-collection mode. (go to experiment, then data → meter screen)
 - a. On the Meter screen, tap Mode. Change the mode to Events with Entry.
 - b. Enter the Name (Volume) and Units (mL). Select OK.
3. To obtain the best data possible, you will need to correct the volume readings from the syringe. Look at the syringe; its scale reports its own internal volume. However, that volume is not the total volume of trapped air in your system since there is a little bit of space inside the pressure sensor.

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.
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. Write a verbal statement that correctly expresses Boyle's law.

EXTENSION (REQUIRED-SEE PEDERSEN)

1. To confirm that an inverse relationship exists between pressure and volume, a graph of pressure *vs.* *reciprocal of volume* ($1/\text{volume}$) may also be plotted. To do this using LabQuest:
 - a. Tap the Table tab to display the data table.
 - b. Choose New Calculated Column from the Table menu.
 - c. Enter the Name ($1/\text{Volume}$) and Units ($1/\text{mL}$). Select the equation, A/X . Use Volume as the Column for X , and 1 as the value for A .
 - d. Select OK.
2. Follow this procedure to calculate regression statistics and to plot a best-fit regression line on your graph of pressure *vs.* $1/\text{volume}$:
 - a. Choose Graph Options from the Graph menu.
 - b. Select Autoscale from 0 and select OK.
 - c. Choose Curve Fit from the Analyze menu.
 - d. Select Linear as the Fit Equation. The linear-regression statistics for these two data columns are displayed in the form:

$$y = mx + b$$

where x is $1/\text{volume}$, y is pressure, m is a proportionality constant, and b is the y -intercept.

- e. Select OK. If the relationship between P and V is an inverse relationship, the graph of pressure *vs.* $1/\text{volume}$ should be direct; that is, the curve should be linear and pass through (or near) the origin. Examine your graph to see if this is true for your data.