Chromebooks

Key 2018

Experiment

6

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 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.

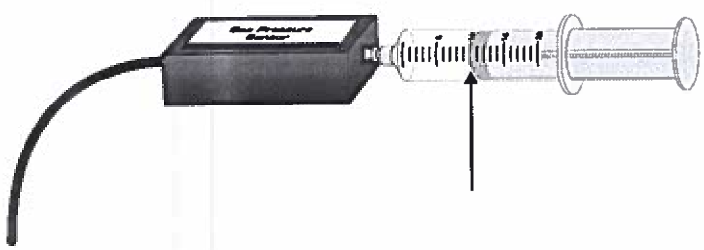


Figure 1

MATERIALS

Computer (Chromebook)
Vernier Go!Link
Vernier Graphical Analysis 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 Vernier Go!Link to the Vernier Gas Pressure Sensor. Connect to Chromebook via USB.
   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 2) is positioned at the 10.0 mL mark.
   c. Attach the 20 mL syringe to the valve of the Gas Pressure Sensor.

2. Prepare the computer for data collection by opening the Vernier Graphical Analysis app on your Chromebook. If the connections are correct, the y-axis will read "Pressure (kPa) and the x-axis will read "Time (s)".

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.

   To account for the extra volume in the system, you will need to add 0.8 mL to your syringe readings. For example, with a 5.0 mL syringe volume, the total volume would be 5.8 mL. *It is this total volume that you will need for the analysis.*

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. Click COLLECT and 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 stabilizes.

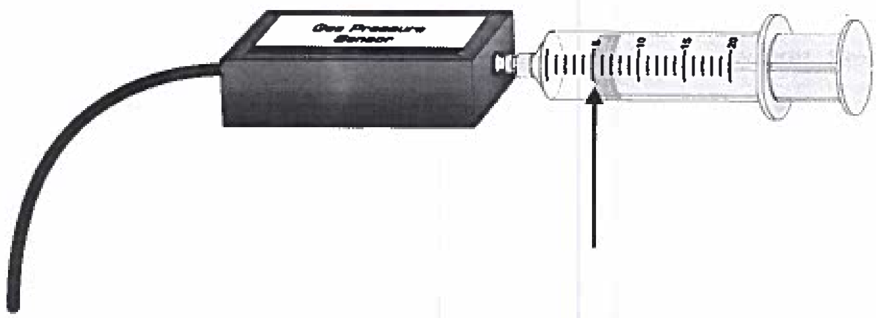


Figure 2

   b. When the pressure reading has stabilized, click STOP. (The person holding the syringe can relax after STOP is clicked.) Record the total gas volume (in this case, 5.8 mL) in your data table. Remember, you are adding 0.8 mL to the volume of the syringe for the total volume. Look at your graph to see where the pressure stabilized. Click anywhere on that section, and the pressure value will pop up. Record that pressure in kPa in your data table.

   c. Click COLLECT and move the piston to the 7.0 mL line. When the pressure reading has stabilized, click STOP and record the total volume, 7.8 mL and the pressure measured in your data table.

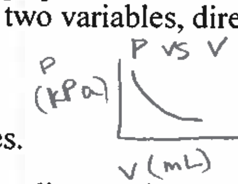
   d. Continue this procedure for syringe volumes of 9.0, 11.0, 13.0, 15.0, 17.0, and 19.0 mL.

5. In your data table, record the pressure and volume data pairs displayed in the table (or, if directed by your instructor, print a copy of the table).

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:

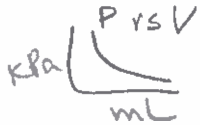
   a. Open Google Sheets.

   b. Create a graph to see the relationship between variables.



7. Once you have confirmed that the graph represents either a direct or inverse relationship, screenshot the graph, and insert below.

INSERT GRAPH



DATA AND CALCULATIONS 2018

Volume (mL)	Pressure (kPa)	Constant, *k* (*P/V* or *P•V*)
5.8	195.16	1132
7.8	143.42	1114
9.8	114.63	1123
11.8	93.45	1103
13.8	79.47	1097
15.8	69.38	1096
17.8	61.59	1096
19.8	55.40	1097

PROCESSING THE DATA

1. Using your graph and data table, what happens to the pressure when the volume is ***doubled***? Hint: What is the pressure when the volume is 5.0 mL? What is the pressure when the volume is 10.0 mL? What is the relationship? V is doubled ⇒ P is halved

   5.8 mL = 195.16 kPa   ~11.6 mL = 97.58 kPa

2. Using the same technique as in Question 1, what does your data show happens to the pressure if the volume is ***halved*** from 20.0 mL to 10.0 mL? Show the pressure values in your answer. V is halved ⇒ P is doubled

   20.0 mL = ~55 kPa   10.0 mL = ~110 kPa

3. Using the same technique as in Question 1, what does your data show happens to the pressure if the volume is ***tripled*** from 5.0 mL to 15.0 mL? Show the pressure values in your answer. V is tripled ⇒ P 1/3

   6.0 mL = ~190 kPa   18.0 mL = ~60 kPa

4. From your answers to the first three questions ***and*** the shape of the curve in the plot of pressure *vs.* volume, do you think the relationship between the pressure and volume of a confined gas is direct or inverse? Explain your answer.

   As V↑ P↓

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. V x 4 ⇒ P/4

   10.0 mL = ~110 kPa   40.0 mL = ~27.5 kPa

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. V/4 ⇒ P x 4

   10.0 mL = ~110 kPa   2.5 mL = ~440 kPa

7. What experimental factors are assumed to be constant in this experiment?

   Temp & # of particles

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.

   meh... not bad!

10. Using P, V, and k, write an equation representing Boyle's law. Write a verbal statement that correctly expresses Boyle's law.

    $V \cdot P = k$