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.

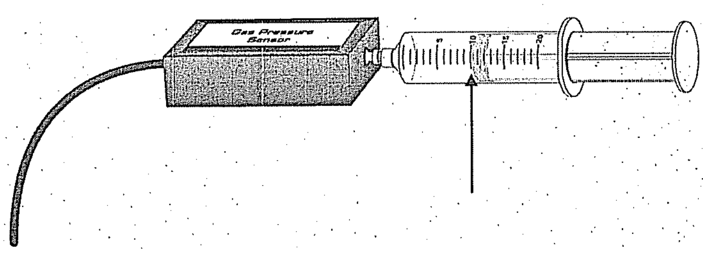


Figure 1

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Vernier Gas Pressure Sensor
20 mL gas syringe

PROCEDURE

1. Prepare the Gas Pressure Sensor and an air sample for data collection.
2. Prepare the computer for data collection by opening the file "06 Boyle's Law" from the *Chemistry with Computers* folder of Logger*Pro*.
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. Click [Collect] to begin data collection.
5. 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 stabilizes.

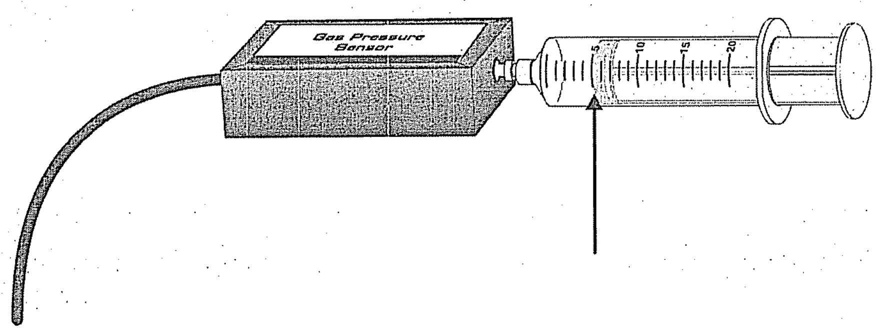


Figure 2

   b. When the pressure reading has stabilized, click [Keep]. (The person holding the syringe can relax after [Keep] is clicked.) Type in the total gas volume (in this case, 5.8 mL) in the edit box. Remember, you are adding 0.8 mL to the volume of the syringe for the total volume. 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. Move the piston to the 7.0 mL line. When the pressure reading has stabilized, click [Keep] and type in the total volume, 7.8 mL.
   d. Continue this procedure for syringe volumes of 9.0, 11.0, 13.0, 15.0, 17.0, and 19.0 mL.
   e. Click [Stop] when you have finished collecting data.
6. 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).
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:
   a. Click the Curve Fit button, [icon].
   b. Choose Variable Power (y = Ax^n) from the list at the lower left. Enter the power value, *n*, in the Power 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].

8. Once you have confirmed that the graph represents either a direct or inverse relationship, print a copy of the graph, with the graph of pressure *vs.* volume and its best-fit curve displayed.

9. With the best-fit curve still displayed, proceed directly to the Processing the Data section.

DATA AND CALCULATIONS

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

PROCESSING THE DATA

1. From 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.

2. 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, $k = P \bullet V$. 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.

Name: ______________________________

1) The kinetic molecular theory assumes that the particles of an ideal gas

A) are arranged in a regular geometric pattern
B) are in random, constant, straight-line motion
C) have collisions that result in the system losing energy
D) have strong attractive forces between them

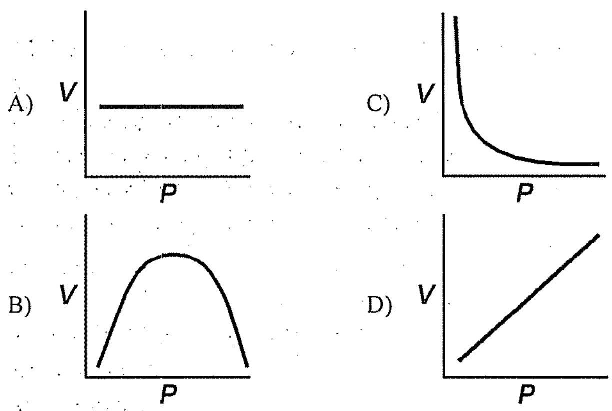
2) In a gaseous system at equilibrium with its surroundings, as molecules of *A*(g) collide with molecules of *B*(g) without reacting, the total energy of the gaseous system

A) increases
B) decreases
C) remains the same

3) Helium is most likely to behave as an ideal gas when it is under

A) high pressure and high temperature
B) low pressure and high temperature
C) low pressure and low temperature
D) high pressure and low temperature

4) Which graph *best* represents the pressure-volume relationship for an ideal gas at constant temperature?



5) A sample of oxygen gas is sealed in container *X*. A sample of hydrogen gas is sealed in container *Z*. Both samples have the same volume, temperature, and pressure. Which statement is true?

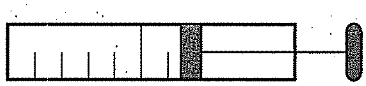
A) Containers *X* and *Z* both contain the same mass of gas.
B) Container *X* contains fewer gas molecules than container *Z*.
C) Containers *X* and *Z* both contain the same number of gas molecules.
D) Container *X* contains more gas molecules than container *Z*.

6) At STP, 4 liters of O_2 contains the same total number of molecules as

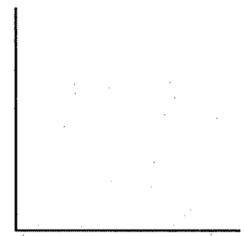
A) 1 L of NH_3
B) 4 L of CO_2
C) 2 L of Cl_2
D) 8 L of He

Questions 7 and 8 refer to the following:

The diagram below shows a piston confining a gas in a cylinder.



7) Using the set of axes below, sketch the general relationship between the pressure and the volume of an ideal gas at constant temperature.

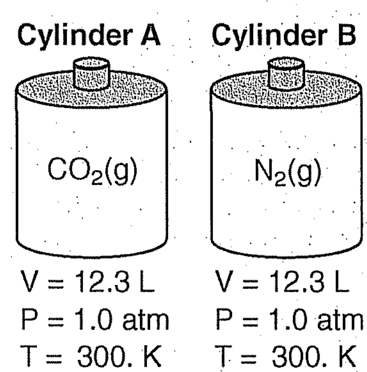


8) The gas volume in the cylinder is 6.2 milliliters and its pressure is 1.4 atmospheres. The piston is then pushed in until the gas volume is 3.1 milliliters while the temperature remains constant. Calculate the pressure, in atmospheres, after the change in volume. [*Show all work.*]

9) A weather balloon has a volume of 52.5 liters at a temperature of 295 K. The balloon is released and rises to an altitude where the temperature is 252 K.

What Celsius temperature is equal to 252 K?

10) Cylinder *A* contains 22.0 grams of CO_2(g) and cylinder *B* contains N_2(g). The volumes, pressures, and temperatures of the two gases are indicated under each cylinder.



Explain why the number of molecules of N_2(g) in cylinder *B* is the same as the number of molecules of CO_2(g) in cylinder *A*.