Experiment: Boyle's Law

PART I: Pressure-Volume Relationship in Gases (Boyle's Law)

INTRODUCTION

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 pressure sensor (see Figure 1). According to the Ideal Gas Law for an enclosed gas (with n particles), the product of gas pressure (P) and volume (V) should be a constant value at constant temperature (T) or:

$$PV = nRT = \text{constant } \{\text{when n \& T are constant}\}$$

where R = 8.31 J/mol·K is called the Universal Gas Constant.

In Figure 1, when the volume of the syringe is changed by moving the piston in or out, a corresponding change in the pressure exerted by the confined gas should result. This pressure change will be monitored using a 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 with LoggerPro. From the data and graph, the mathematical relationship between the pressure and volume of the confined gas will be identified. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.

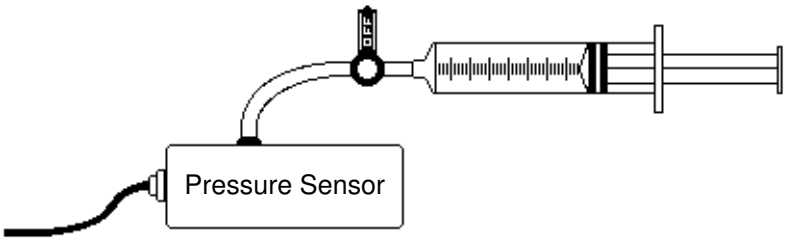

Figure 1

PRELIMINARY QUESTIONS

1. Obtain a small syringe and position the plunger at about the midway point. Place a closed stopcock over the small opening. Gently push the plunger inward about ½ mL. Next press the plunger further into the syringe (2 or 3 mL). How does the effort to press the plunger a short distance into the syringe compare to pressing it further?

2. Now, gently pull the plunger outward about ½ mL. then pull the plunger further outward (2 or 3 mL). How does the effort to pull the plunger a short distance out of the syringe compare to pulling it further?

3. Based on your observations above, what you say about the relationship between push/pull force and volume for an enclosed gas? Between pressure and volume?

PROCEDURE

1. Prepare the Pressure Sensor and an air sample for data collection.
   a. Plug the Pressure Sensor into CH 1 of a LabPro Interface that is connected to a computer.
   b. Move the piston of the syringe until the front edge of the inside black ring is positioned at the 10.0 mL mark. Connect the syringe to the Pressure Sensor.
2. Open the LoggerPro experiment file: "06 Boyle's Law" from the Chemistry with Vernier directory.
3. Begin data collection and collect 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.
   b. When the pressure reading has stabilized, click "Keep". Type "5.0" in the edit box to record the volume in mL then "Enter" to keep this data pair.
4. Repeat the Step 5 procedure for volumes of 7.5, 10.0, 12.5, 15.0, 17.5, and 20.0 mL. When you are finished, click on "Stop" to end data collection.
5. Record the pressure and volume data pairs in the Data Table below.
6. Examine the graph of pressure vs. volume. Based on this graph and what you know about the ideal gas law, what kind of mathematical relationship you think exists between these two variables, direct or inverse?
7. To see if you made the right choice, use the Curve Fit function to obtain the best (and simplest) fit for your graph. Choose Variable Power ($y = Ax^n$) from the list at the lower left then enter the value of *n* in the Degree/Exponent edit box that best represents the relationship shown in the graph (e.g., type "1" if direct, "-1" if inverse).
8. Once you have fit your data, cut-and paste your graph into Microsoft WORD.

DATA AND CALCULATIONS

Volume (mL)	Pressure (kPa)	Constant (P/V or P·V)
	Average:	
	Uncertainty (±):	

PROCESSING THE DATA

1. From 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 (linear) or inverse? Explain your answer.

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

3. Create 2 "calculated" columns in LoggerPro for: (a) **P·V** and (b) **P/V**, respectively. For which column of data are the values roughly the same? Enter these values in the above table then calculate the average and uncertainty.

4. Using the appropriate expression from (3), write an equation representing Boyle's law (i.e. PV= constant or P/V = constant). Write a statement in your own words that correctly expresses Boyle's law, including the value of the constant.

5. Using the value of the constant above and the room temperature (in K), estimate the number of gas particles in the syringe during this experiment, i.e. apply the Ideal Gas Law.