Experiment: Gas Laws

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). When the volume of the syringe is changed by moving the piston, a change in the pressure exerted by the confined gas results. This pressure change will be monitored using a pressure sensor interfaced to a computer. 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.

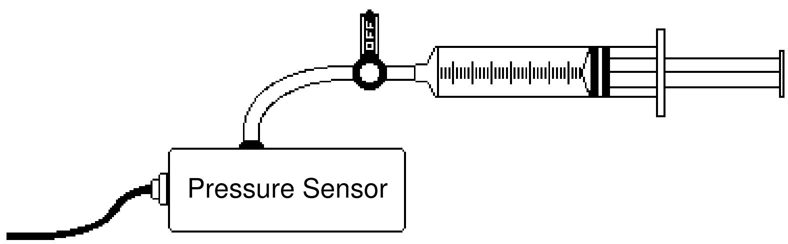

Figure 1

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.

PART II. Pressure-Temperature Relationship in Gases

In order to investigate the pressure-temperature relationship in gases, we will use a closed container whose volume will remain constant and we will change the temperature of the gas enclosed by submerging the container in warm water.

PROCEDURE:

1. Obtain and wear goggles and heat gloves.

2. Prepare a boiling water bath. Pour about 500mL into a 1-liter beaker and place it on the hot plate. Use the Medium (not High!) setting for the hot plate.

3. Prepare an ice-water bath, a room-temperature bath and a warm water bath (about 60 degrees Celsius)

4. Plug Temperature sensor in the CH2 port.

5. Insert a rubber-stopper assembly into a Erlenmeyer flask. Connect the valve of the Pressure Sensor to the plastic tubing coming from the ruber stopper assembly. The pressure sensor is now ready to measure the pressure of the air trapped inside the Erlenmeyer flask.

6. Open the LoggerPro experiment file "07 Pressure-Temperature".

7. Click " Collect" to begin data collection.

8. Collect pressure v. temperature data for your air sample:
   a. Place the flask into the ice water bath, making sure that the entire flask is covered
   b. Place the temperature sensor in the bath.
   c. When the pressure and temperature readings are stable, click "Keep". You have saved the first pressure-temperature data pair.

9. Repeat Step 8 using room temperature bath.

10. Repeat Step 8 using warm water bath.

11. Repeat Step 8 using boiling water bath.

12. Click "Stop" when you ave finished collecting data. Record the pressure and temperature values on your table.

13. Examine your pressure vs temperature graph. *What is the shape of the graph*?

14. Use the Linear Fit tool and observe the approximate point where the fit line intercepts the temperature axis. *What is the significance of this point*?

15. Create a new "Calculated Column" to convert your temperature data to the Kelvin scale. Label the column "Absolute Temperature".

16. Click on the vertical-axis label, select "Pressure" and click "OK". In the same way, select the "Absolute Temperature" to be displayed on the horizontal axis.

17. Cut-and-paste the graph into WORD and print it.

18. A better way to determine the value for absolute zero is to plot the **Celsius temperature on the y axis** and the **pressure on the x axis.**

Since Absolute zero is the temperature at which the pressure theoretically becomes zero, the y-intercept will represent the value of absolute zero on Celsius scale.

19. Rescale the graph: -300 to 200 Celsius on the y axis and 0 to 150 kPa on the x axis then fit the graph to a line (Linear regression). The y-intercept of the best fit equation represents absolute zero on Celsius scale. *Don't forget to display the standard deviations for the slope and y-intercept.*

DATA AND CALCULATIONS:

Water Bath	**Pressure (KPa)**	**Temperature (°C)**	**Temperature (K)**	**Constant (P/T or P·T)**
Ice Water				
Room temperature				
Warm water				
Boiling water				
			Average	
			Uncertainty	

Analysis Questions:

1. In order to perform this experiment, what factors were kept constant?

2. Express in words a relationship between pressure and absolute temperature, based on your graph.

3. Write a general equation to express the relationship between pressure and temperature using the symbols P, T and the fit values in your graph.

4. One way to determine if the relationship is direct or inverse is to find a proportionality constant from the data. Create 2 "calculated" columns in LoggerPro for: (a) **P·T** and (b)

P/T, respectively. For which column of data are the values roughly the same? Enter these values in the above table.

5. How "constant" are your values? Calculate the average and uncertainty of this constant.

6. According to this experiment, what should happen to the pressure of the gas if the Kelvin temperature is doubled? Check this assumption by finding the pressure at -73 Celsius (200K) and 127 celsius (400K). How do these pressure values compare?

7. What is your estimated value for absolute zero in Celsius (including uncertainty)? Does this value agree with the accepted value? Calculate the % error.