Gas Laws: Pressure, Volume, and Temperature

Introduction

Pressure, volume, and temperature are properties of gases that reveal their relationships when any one of them is varied. Changing the temperature of a gas may change its volume or pressure, but how? What are the mathematical relationships between these properties? Are there limits to them? Scientists have discovered through the study of properties of gases that there is indeed a theoretical limit to temperature, called absolute zero. Studying the relationships between the properties of gases enables one to predict their values under given conditions.

Learner Outcomes

Upon completion of this laboratory activity, the student should be able to

- use the pressure probe to carry out experiments with gases.
- determine the relationship between the pressure and the volume of a gas.

Background

This experiment will draw upon your experience with computer-based laboratory methods from previous lab activities utilizing the computer. In the first part of the experiment, you will see how changes in volume affect the pressure of a gas. In the bonus part, you will have the opportunity to study the relationship between the temperature and pressure of a gas.

You will use the *Logger Pro* program and a pressure-sensing probe. The data you collect in the first part of the experiment will be non-time-based, meaning you will be entering values manually. As with all computer-based experiments, your analysis of the data is the most important and precise calibration of the probes is critical.

Preparing Logger Pro for Measurements

Connect the pressure sensor to Channel 1 of the LabPro™ interface. You may need to an adapter to connect the probe to the interface. Open the *LoggerPro* application from the Start menu or desktop. Check your probe to see whether it is labeled "Pressure Sensor" or "Gas Pressure Sensor" and open the appropriate **Boyle's Law** file for your specific pressure sensor probe from the **Probes & Sensors** folder of the **Experiments** folder. Next, click on the **LabPro** icon on the toolbar, then on **Channel 1**. Finally, select the calibration option that will enable you to make your measurements in "mm Hg".

SAVE YOUR WORK!

REMINDER: *Save your data **early and often** in order to avoid the accidental loss of your work. Use the following convention for naming your files: "Lastname Firstname Gases" (include both names if you are working in pairs), saving to the H: drive and/or your own flash drive.* Backup all your computer data by saving to your own disk and/or emailing a copy to yourself.

Procedure 1: The Relationship Between Pressure and Volume

1. Set the plunger of the syringe to $\frac{1}{10}$ the capacity of the syringe (the 2.0-mL mark, if using a 20-mL syringe). The volume is read from the edge of the bottom rib of the plunger.

2. Attach the syringe to the connector at the end of sensor. If using a sensor labeled "Pressure

Sensor", turn the blue valve so it is off to the atmosphere (perpendicular to the tubing).

3. Decide which of you will control the syringe (you or your lab partner), and which will enter the volumes into the computer. Click Collect on the toolbar to begin collecting data.

4. Read the volume on the syringe and click Keep. Enter the volume to the nearest ±0.1 mL into the data box that opens and click "OK". The pressure will automatically be recorded.

5. Pull the plunger back in increments of $\frac{1}{10}$ the capacity of the syringe and manually enter the volume each time as before (2.0-mL increments, if using a 20-mL syringe). If you did this correctly, you should have 10 readings when finished.

   NOTE: Hold the plunger firmly and steadily. It will become increasingly difficult to pull back with each reading. Do not click on Keep *until each volume reading is ready to be made.*

6. Click Stop once you have taken all the readings.

   REMINDER: When using the Interface, get in the habit of saving your file and storing the latest run whenever you complete a trial. Failure to do so may result in all of your data being lost in an experiment.

7. Copy and paste the data into *Sheet 1* of an *Excel* spreadsheet. *Save using the following convention for naming your files: "Lastname Firstname Gases" (include both names if you are working in pairs), saving to the H: drive and/or your own flash drive.*

8. It turns out that the volume reading on the syringe is not equal to the volume of the gas, since some gas occupies the space inside the tubing and inside the pressure sensor. To correct for this, add a new column to your spreadsheet between the existing volume and pressure columns, called corrected volume. In this column, add 0.5 mL to each of your syringe readings if your sensor was a "Gas Pressure Sensor" and 2.3 mL to each of your readings if your sensor was a "Pressure Sensor". To abbreviate, use V_s for syringe readings, V for the corrected volumes, and P for the pressure.

9. Use the curve-fitting techniques you learned in Spreadsheet Lab II to determine a mathematical relationship between pressure (P) and corrected volume (V). Assign pressure to the y-axis. Then plot P vs. each V, V^2, $1/V$, $1/V^2$, $\log V$, and 10^V. Use the trendline analysis to determine a mathematical equation for the relation. On the plot of P vs. $1/V$ and P vs. $1/V^2$, the y-intercept should be set to zero. Why? Try it and see what happens.

10. Keep only your best-fit linear plot, showing the mathematical equation and your experimental data. Does your data show that pressure and volume are directly proportional, inversely proportional, or some other relationship? *(Remember to consider significant figures in your spreadsheet and graph.)*

11. Repeat steps 1-10, except set the initial reading of the plunger to $\frac{1}{5}$ the capacity of the syringe in step 1 (the 4.0-mL mark, if using a 20-mL syringe). This should give you 9 readings on your second trial. On this trial, copy and paste this data into *Sheet 2* and perform your analysis.

12. Repeat steps 1-10 again, except set the initial reading of the plunger to $\frac{2}{5}$ the capacity of the syringe in step 2 (the 8.0-mL mark, if using a 20-mL syringe). This should give you 7 readings on your third trial. On this trial, copy and paste this data into *Sheet 3* and perform your analysis.

13. When you are finished with all of the trials, make a new column on Sheets 1-3 that calculates the product of *P* and *V*. At the bottom of this column, use a formula to calculate the average of the product on each sheet.

Laboratory Report

For this experiment, you and your partner may submit a group report. You also have the option of submitting an individual report. If you do so, please signify on your report that it is an individual report (by placing your name first and underlining it). This lab will need to include a title, procedure, results, discussion, and references. Guidelines for Laboratory Reports may be found at http://webs.anokaramsey.edu/chemistry/Chem1061/Labs/Reports/Laboratory%20Reports.htm.

Follow your instructor's directions for submitting this lab report. If you submit it electronically, please submit a single *Word* file for your entire report, including graphs and appendices (you may embed the tables and graphs into your Word document). Use the *"lastname_lab8"* file-naming convention. If you email the report, use "Chem 1061: Gas Laws Lab" as the subject line.

If you submit the report on paper, please print out the tables and graphs from Excel and staple them to the back of the laboratory report. Remember that you will then need to provide sample calculations for one of the trials to show how you obtained your data.

For the discussion and conclusions section, there are a lot of issues which should be addressed. Steps 9 and 10 of the procedure had questions about the data which should be answered here. In addition, you should also address the following topics:

1. How does the average product of *PV* compare to the slope of your best-fit line for each trial?

2. For each of the trials, calculate the pressure in the syringe if the reading on the syringe, V_s, was 15 mL. Show your calculation.

3. What happens to the magnitude of the slope with each successive trial? Why does it change?

4. Why should the *y*-intercept be set to zero on the plot of *P* vs. $1/V$ and *P* vs. $1/V^2$? Does your data show that pressure and volume are directly proportional, inversely proportional, or some other relationship?

5. What are some sources of error or uncertainty in this experiment? Are there ways you could reduce the amount of error or uncertainty in this experiment? If so, how?