Lab 10: Gas Pressure and Volume[1]

Goals: Improve communication and teamwork capacities**;** Improve confidence in hands-on work with equipment; Improve ability to make, describe, and record observations; use a pressure sensor attached to a syringe or a syringe-flask combination to investigate the relationship between pressure and volume at constant temperature for a fixed amount of gas; use linearization of data to determine an unknown volume.

Equipment: You will be oriented to the equipment, set-up, and use of the equipment for today's investigation. Make sure you include sketches of the various experimental set-ups in your lab notebook.

Groups & Lab Notebook: Groups of 2. Update Table of Contents. General Lab Notes guidelines.

Part 0: Getting Started. You will be oriented to equipment and today's investigations in the opening remarks.
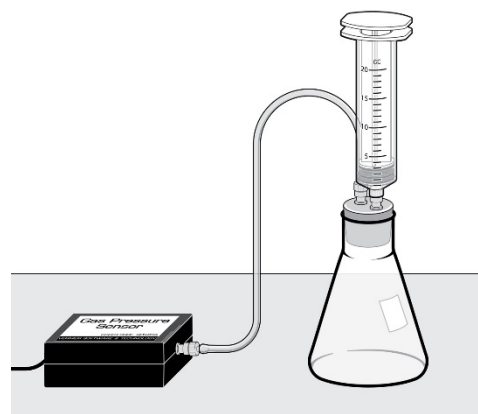
Part 1: Pressure Sensor and Syringe

1. Attach the pressure sensor to the LabQuest and connect to the computer. Launch LoggerPro.
2. Set the syringe to the volume indicated. Attach the syringe to the pressure sensor as in the figure.
3. Note the pressure at this volume.
4. Slowly decrease the **volume** to ½ of its original value. Note the new pressure.
5. Slowly adjust the plunger so that the **pressure** is ½ of its original value. Note the corresponding volume.
6. Slow processes like this where no care was taken to insulate the gas from its surrounding can be treated as constant T processes. Additionally, this was a fixed n process. Use this information and the ideal gas law to make sense of the measurements you made – are your results consistent with the predictions of the ideal gas law?
7. Now, take a series of careful measurements. Disconnect the syringe from the pressure sensor. Rather than Time-based mode, you will collect data in Events with Entry mode in this experiment. Change the data-collection mode and enter **volume** as the Column Name and **mL** as the Units.
8. Set the syringe to the volume indicated. Connect the syringe to the pressure sensor.
9. Begin data collection. Click or tap Keep and enter the appropriate reading in the volume field.
10. Slowly pull on the piston until the volume has increased by 2 mL from its previous position. When the pressure reading stabilizes, click or tap Keep and enter the volume.
11. Repeat this step, each time increasing the volume by 2 mL until you have at least 6 data points (more is better if possible).
12. Produce a graph of pressure vs. volume. Make sure to plot individual data points not connected by line segments.
13. Show that the ideal gas law $PV = NkT$ can be solved for pressure to obtain $P = NkT/V$. Since NkT is a constant, call it $A = NkT$ so that $P = A/V$. This is an inverse relationship.
14. Determine how well your data follows this inverse relationship by doing a Curve Fit of your data to an Inverse function. You may have to Try Fit several times, and may have to put in a seed value for A.
15. Show your graph to your instructor.
16. Record the best-fit value for A along with its uncertainty.
17. Save your graph for inclusion in your lab notebook. Save your LoggerPro file to the appropriate folder in the Workspace with a useful name including your group member names.

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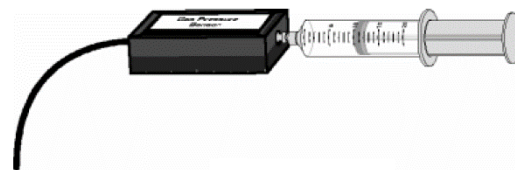
[1] All images from Vernier. Lab based on experiments in Advanced Physics – Beyond Mechanics, by Vernier

Part 2: Pressure Sensor and Syringe+Flask

1. Disconnect the syringe from the pressure sensor and set it to 0 mL by pushing the plunger all the way forward. Set up your system as in the figure with the 0 mL syringe.
2. Re-launch LoggerPro. As before, you will collect data in Events with Entry mode. Change the data-collection mode and enter **syringe volume** as the Column Name and **mL** as the Units.
3. Start data collection. Click or tap Keep and enter 0 (the reading for the syringe) in the volume field. You might wonder about this choice (note what you are wondering about if this the case), and we will address this later.
4. Slowly pull on the piston until the volume reading on the syringe has increased to 2 mL. When the pressure reading stabilizes, click or tap Keep and enter the syringe reading.
5. Repeat this step, each time increasing the volume by 2 mL until you have at least 6 data points (more is better if possible).
6. Produce a graph of pressure vs. volume. Make sure to plot individual data points not connected by line segments.
7. What strikes you about this graph, especially as compared to the nominally similar graph from Part 1? Discuss with your partner why you think this has occurred. Then, discuss with your faculty.
8. Your discussion should have led you to realize that in this scenario, the volume reading on the syringe is not the volume of the system – the system volume is comprised of the volume of the flask + tubing (which is fixed) + the volume of the syringe (which is varied). Then, $V = V_0 + V_{syringe}$ where V_0 = volume of flask + tubing is a constant.
9. How can we account for V_0? One way is to make a new calculated column for system volume where you keep guessing a value for V_0 and keep fitting until you think you have a good fit. This is an inefficient and inelegant method.
10. Instead, we will use a method known as linearizing. Show that for this case, the ideal gas law becomes
$V_{syringe} = A\left(\frac{1}{P}\right) + V_0$ (where $A = NkT$ is a constant as before).
11. This is a linear equation of the form $y = mx + b$, where $x = \frac{1}{P}$ and $y = V_{syringe}$. What do m and b correspond to, both in terms of symbols and physical quantities, and in terms of the linear graph?
12. So, if we plot $V_{syringe}$ vs. $\frac{1}{P}$ and obtain a straight line (hence the term linearization), we can show that the ideal gas law applies to this situation and obtain V_0 at the same time.
13. Create a new calculated column for $\frac{1}{P}$ called reciprocal pressure. Figure out the appropriate units.
14. Plot $V_{syringe}$ vs. $\frac{1}{P}$, show individual data points, and obtain a best-fit straight line (use Curve Fit instead of Linear fit so you can also get the uncertainties in A and V_0.) Record the best-fit values for A and V_0 along with their uncertainties.
15. Save your graph for inclusion in your lab notebook. Save your LoggerPro file to the appropriate folder in the Workspace with a useful name including your group member names.

Extensions
1. From your results in Parts 1 and 2, how would you determine the amount of gas (N) in the two cases?
2. The pressure sensor actually has a little chamber incorporated in it. Therefore, the assumption in Part 1 that the syringe volume was the system volume is not quite accurate. The effect is not as pronounced as in Part 2 because the pressure sensor chamber volume is relatively small. Reproduce your analysis from Part 2 to determine the pressure chamber volume.