**Studying Boyle’s Law**

# Introduction

Boyle’s Law states that the volume of a fixed amount of ideal gas is inversely proportional to its pressure at a constant temperature:

 or 

where *V* is the volume, *p* is the pressure, and *k* is a constant.

This also means that the product of volume and pressure of a given amount of gas remains the same at a given temperature:



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|  |
| Figure 1. Pressure sensor with a syringe |

In this experiment you will investigate the relationship between the volume and the pressure of an air sample enclosed in a syringe at a constant temperature. The syringe is attached airtight to a pressure measuring setup, which records the pressure in the syringe.

As an example, consider a 60-mL syringe attached to the pressure sensor with the plunger being at the 30-mL position[[1]](#footnote-1). At this point the pressure inside the syringe is the same as the atmospheric pressure, which can be read from the screen (e.g. 1.000 atm) at room temperature (e.g. 21.0 oC).

The amount of air in the syringe (using the room temperature readings of *T*=21.0 oC and *V*=31.0 mL)[[2]](#footnote-2):



The plunger is moved in in a step of 2.0 mL to 14.0 mL, then from 30 mL to 48 mL outwards, while the pressure and volume are recorded. The obtained p vs. V and p vs. 1/V graphs are shown in Figure 2 and Figure 3, respectively.

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| --- | --- |
|  |  |
| Figure 2. p Vs. V graph of 30.0 mL gas in a syringe | Figure 3. p vs. 1/*V* graph of sample data |

Using the Ideal Gas Law, the slope of the *p* vs. 1/*V* graph *should be* with constant *T* and *n*:



From the slope *R* can be estimated:



The % error of the measurement is assessed by comparing the theoretical and experimental estimate of *R*:



(units are omitted as they cancel out)

# Procedure

1. For setting up the experiment, execute the data collection, downloading the results, and performing the calculations, please refer to the Appendix.

# Data Table/Calculations

1. Complete the data table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bath | T (oC) | T (K) | V (mL) | V (L) |
| Beaker 1: |  |  |  |  |
| Beaker 2: |  |  |  |  |
| Beaker 3: |  |  |  |  |
| Room temp: |  |  |  |  |
| Beaker 4: |  |  |  |  |
| Beaker 5: |  |  |  |  |

**Note:** For the calculations and graphing use a spreadsheet application (e.g. Excel, see Appendix).

1. Create a plot of *V* vs. *T* (use the converted units). Record the slope and intercept (with units):



Make sure:

* + The graph is properly scaled to maximize the real estate of the graph with your points.
  + The axes are properly labelled with the respective quantities and units.
  + Trendline is added with the equation and R2 value.
  + The numbers on the axes and in the equation (trendline label) are properly formatted with the right number of significant figures.

1. Using the Ideal Gas Law (), calculate the number of moles of air in the syringe using the room temperature data.



1. Using the Ideal Gas Law, and the number of moles of air in the syringe, calculate the expected volume at each temperature.

|  |  |  |
| --- | --- | --- |
| Temperature (K) | Volume (L) | |
| Experimental  (from the table above) | Expected |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

1. Add the expected volume data to your graph with an equation and R2 value
2. Calculate the experimental estimate from the slope and number of moles of the gas in the syringe:



1. Compare the expected and experimental slopes (see the example in the Introduction)
2. In your discussion make sure you include:

* The assessment of your data for accuracy and precision
* The assessment if your data supports Charles Law
* Potential sources of experimental error

# Appendix (setting up Excel)

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| Figure A. The table with data, and the graph with the experimental and calculated values |
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| Figure B. The respective formulae for the calculations |

# Pre-Lab Questions

1. According to Charles’ Law, are volume and temperature directly or inversely proportional to one another?
2. How are you going to make sure that the pressure remains constant through the experiment?
3. Why do you apply silicone grease on the plunger?
4. Assuming there is no experimental error, how would the volume readings change, if at all, if you were placing the syringe in the baths in reverse order (starting with the one with the highest temperature)? Explain.
5. Why do you think you have to cap the syringe?
6. Why do you think you cannot start with a syringe set to 0 mL?
7. What would be the reading with the correct number of significant figures in the syringe shown?



# Post-Lab Questions

1. If your volume measurements for each temperature were smaller than expected, but they fit on a straight line, would the graph be affected, and if so how? Explain.
2. Would the accuracy and precision be affected in the previous situation, and if so how? Explain.
3. What do you think the reason could be for smaller volume readings than expected?
4. Rearrange the Ideal Gas Law ( ) to show that it supports Charles’ Law.
5. Using the rearranged form of the Ideal Gas Law, what is the value of the slope and intercept in terms of variable(s) and constant(s) (not the actual numerical values)?
6. Assume you repeat the experiment with a 60-ml syringe set to 30.0 mL at the beginning. How would the graph look different, if at all? Explain.
7. Assume you repeat the experiment with CO2 instead of air. How would the graph look different, if at all? Explain.

1. 1.0 mL is added to each volume reading to account for the volume of air in the sensor tubing [↑](#footnote-ref-1)
2. The volume reading has two significant figures, however an extra significant figure is carried through the calculations and the final result is rounded properly. [↑](#footnote-ref-2)