Experiment 1:
Verification of Boyle's Law

Name: Aisha Khalid (300009084)
Name: Haziqa Rehman (300011640)

Date Performed: September 13, 2017
Date Due: September 20, 2017

TA: Kimia Jahandar Kojouri

University of Ottawa

EXPERIMENT 1: VERIFICATION OF BOYLE'S LAW

Introduction:

The phenomenon of Boyle's Law can be observed in our everyday life. Discovered in the 1660s by an English scientist named Robert Boyle, Boyle's Law explores the relationship between the pressure and the volume of a gas. Boyle used different masses of liquid mercury and a constant quantity of a gas, air, to explore this relationship. He discovered that by doubling the pressure, the volume become half its original volume, hence decreasing by a factor of two.

A gas syringe can be used to model this relationship. By pulling on the plunger, the volume of the chamber can be adjusted. In a closed system where the nozzle is blocked off, the position of the plunger can be changed, hence increasing the pressure by decreasing the volume and vice versa. Boyle discovered that pressure and volume are inversely proportional to each other and can be modeled by the equations $P_1V_1 = P_2V_2$, $PV=C$ and $P \propto 1/V$ .When multiplying the pressure and volume of a given gas in a closed system with constant temperature, the constant will remain the same. This is because if one of the variable changes, the other variable will change accordingly to compensate for the change resulting in a constant. In an ideal situation, the gas being observed should acquire these properties if the volume or pressure were to change. [1]

However, in the real world, gases do not always act ideally. Conditions where temperatures are low or where the pressure is high are examples of cases where gases do not behave ideally. In cold temperatures, the molecule's movements are a lot slower thus causing the repulsive and attractive forces between the molecules to effect the volume as well. In high pressures, the volume of the molecule becomes a factor and impacts the result, whereas an ideal gas is said to have no volume. In the ideal gas law, $PV=nRT$. On the other hand, for real gases, $PV \neq nRT$ but rather it is $Z= PV/nRT$. In the case of a real gas, Z is the variable of deviation from the ideal gas law. The larger the value, the larger the deviation being that $Z=1$ is the ideal gas variable. [2]

In this experiment, a Vernier Gas Pressure Sensor and a 20 mL gas syringe were used. Using LabQuest2 in addition to the gas sensor, exact values for the pressure due to the compression of the gas (in this case, air) in the syringe for various volumes, were collected. By keeping temperature and the mass of air constant, it is possible to observe how changing the volume of the given gas would affects the pressure.

---

[1]Olmsted, John, et al. *Chemistry*. 2.2 Toronto, John Wiley & Sons Canada Ltd.,

[2]2016.Clark, Jim, and Christian Dowell. "Real Gases." *Chemistry LibreTexts*, Libretexts, 1 Feb. 2016, chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Physical_Properties_of_Matter/States_of_Matter/Properties_of_Gases/Real_Gases. Accessed 19 Sept. 2017.

Materials:

- LabQuest 2
- Vernier Gas Pressure Sensor
- 20 mL gas syringe
- USB key (flash drive)

Procedure:

1. Connect the Gas Pressure Sensor to your LabQuest 2.
    a. On LabQuest 2, and choose New from the File menu.
    b. Adjust the plunger of a plastic 20 mL syringe to your desired volume and choose which markings on the tip of the plunger to use for lining up the volume mark.
    c. Attach the 20 mL syringe to the valve of the Gas Pressure Sensor. Lock the syringe into place by using a half turn. Do not overtighten.
2. Set up the LabQuest 2 data-collection mode by changing the mode to Events with Entry.
    a. Enter the Name and Units for the variables. Select OK. NOTE: Make sure to add a correction of 0.8 mL to every volume reading from the syringe. This is because there is 0.8 mL of space inside the pressure sensor itself.
3. Collect data
    a. Hold the plunger at your initial volume mark. After the pressure reading stabilizes, tap Keep and enter your volume + 0.8, the gas volume in mL. Select OK to proceed.
    b. Move the plunger to change the volume of air in the syringe and hold the plunger in place. Once the pressure reading stabilizes, tap Keep and enter the volume +0.8. Select OK to proceed.
    c. Continue steps in part 3 until you have measured the pressure in the syringe at 6-8 different volumes then stop data collection.
    d. Repeat step 3. a.-c. for a Run 2.
4. Decide which measurement at the original volume to keep.
    a. Examine the plotted points carefully and decide which of the two points at the same volume is better.
    b. Tap the table icon. Choose the original data point for volume that you wish to remove from the graph by tapping on it.
    c. Open the table menu by tapping on the word Table then choose Strike Through Data. Lines passing through the data indicate its removal from the graph.
5. Insert USB into LabQuest2 and save file onto USB by selecting the USB icon.
6. Analyze the graph of your variables to determine the mathematical relationship.
    a. Calculate the average pressure from both runs.

b. Make a graph of Volume vs Pressure and Volume vs Inverse Pressure with appropriate lines/curves of best fit.

Data:

Volume of Gas in Syringe(mL)	Pressure of Gas (kPa)		
	Run 1	Run 2	Average
20.8	**101.50**	**100.25**	**100.88**
18.8	**112.05**	**112.02**	**112.04**
16.8	**126.31**	**125.29**	**125.80**
14.8	**142.55**	**142.30**	**142.43**
12.8	**166.39**	**163.96**	**165.18**
10.8	**197.52**	**193.40**	**195.46**
8.8	**226.08**	**226.08**	**226.08**

Calculations:

1.Boyle's Law Constant: PV=C

Sample Calculation using row 1: C_1 = (20ml)x(100.88kPas)=2098.30 (ml)(kPa)

Average of C from all rows = Sum of all C's/7 = 1828.59

Multiplying the volume by the pressure provides the constant. However, there are 7 sets of volumes of pressures, so to get the average constant, all the C values are added and then divided by 7.

Data Analysis:

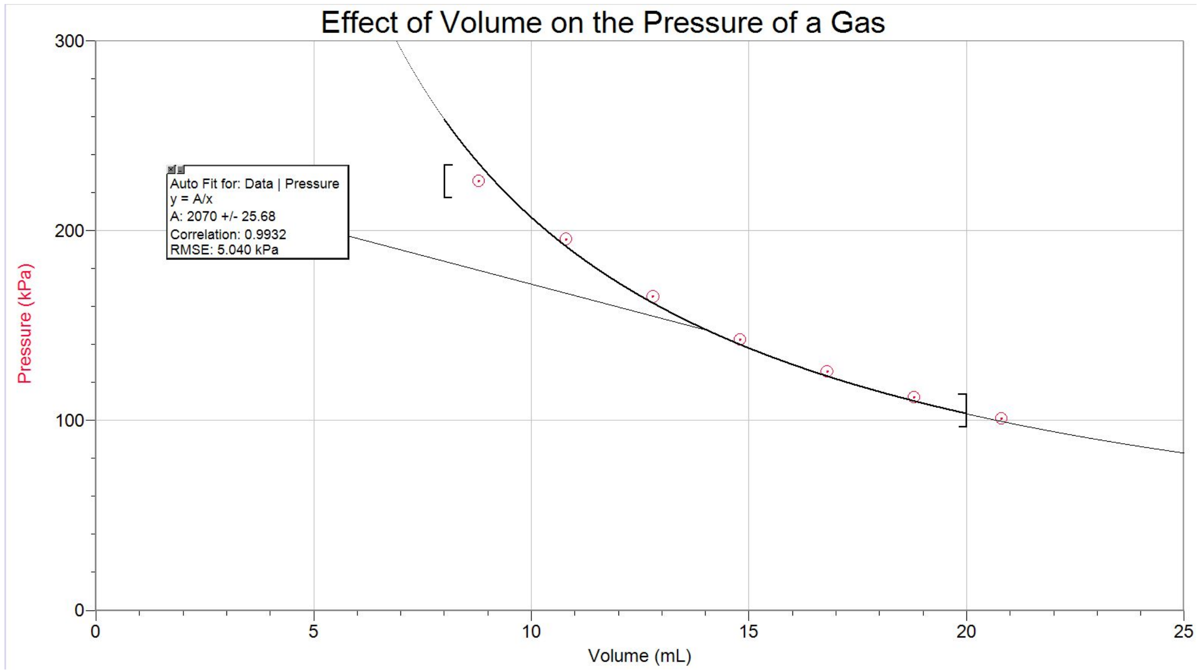

Figure 1. Effect of Volume on the Pressure of a Gas. As Volume increase, pressure decreases. Graph created using the average pressure of a gas from the data table

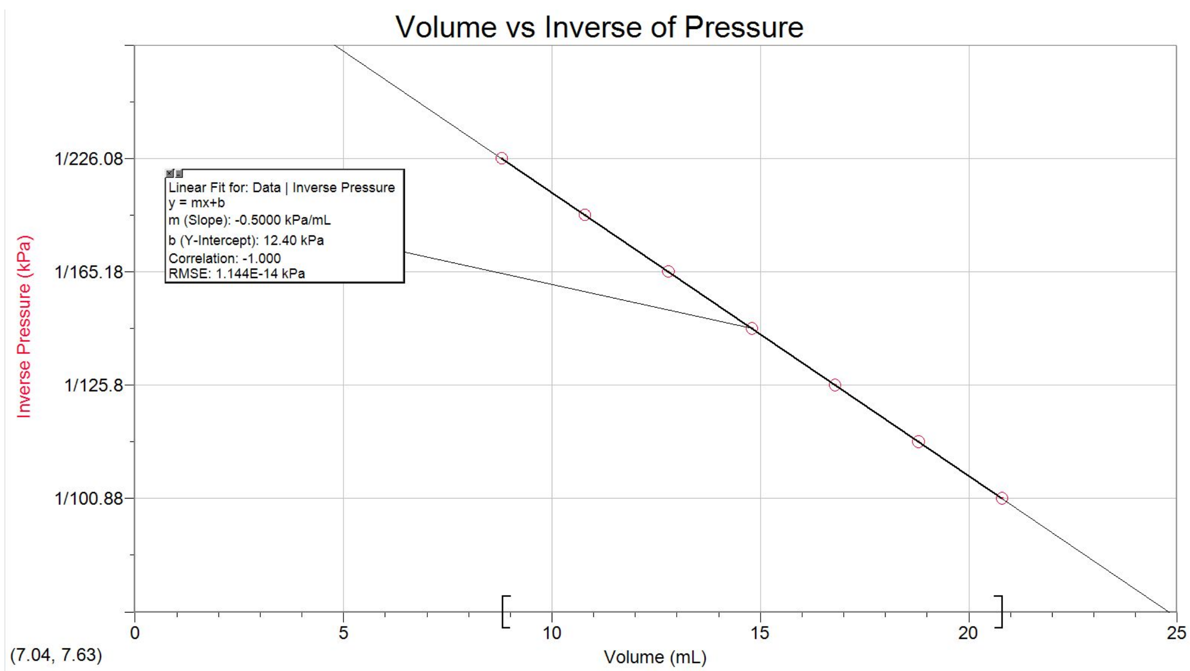

Figure 2. Volume vs Inverse of Pressure. The inverse of the average pressure of the gas. Graph created using the average pressure of the gas from the data table. Demonstrates the a proportional relationship

2. The Boyle's Law equation of PV=C shows that pressure and volume are inversely related. Rearranging this equation gives P=C/V. Therefore, as volume increases, pressure decreases and vice versa, also illustrated by figure.2 above.
Boyle's Law Equation for this Experiment: PV=2017.60 (ml)(kPa)

3. Taking multiple readings of the dependant variable for the same value of the independent variable is always important in order to verify that the data collected in the first run was accurate. Furthermore, retaking the reading for the initial independent variable (20mL in this case) at the end of each run was important as it verified whether the gas was contained in the process of the run which is an important variable for accurate results.

4. Other conditions that Boyle's Law is dependant on is the gas being contained in a system as explained in "Data Analysis: q.3." Another condition is that the temperature must remain constant. The temperature was not measured during the course of the lab and may have fluctuated marginally, however the effect would have been negligible as the data was taken over a small time interval and the temperature would not have changed significantly so quickly.

<u>**Discussion:**</u>

Plotting the data points on a graph of pressure vs volume (Figure 1.) produces a graph which can be modelled by a curve of best fit. Plotting a graph of volume vs the inverse of pressure clearly shows a linear relationship (figure 2.) as the graph represents an inverse relationship. This demonstrates that the curve of best fit for the graph of figure 1. is to the exponent of 1 therefore it can be represented by the equation P=C/V. Therefore this demonstrates the same relationship as stated by Boyle's Law. However looking at the graph of the volume vs pressure (Figure 1.) shows that the data points are not all exactly on the the curve. Additionally, the constant C was found by the graphing software to be 2070 +/- 25.68 whereas the calculated constant from Calculations 1. was 1828.59. This inaccuracy could be due to the sources of error below.

There were a few possible sources of error in this experiment. Temperature as explained in "Discussion q.4" is one possible source of error. The fact that gases are not ideal in the real world as explained in the introduction is another. Also, the accuracy of the volume measurements was a source of error as keeping the syringe plunger at the appropriate measurement became difficult as the pressure increased which could explain the data points being farther away from the curve of best fit at smaller volumes as seen in fig.1. Lastly, the two runs of the experiment shows the varying pressures that were measured for the same volume and demonstrates the breath of the sources of error. For example, for a volume of 10.8 mL, a pressure of 197.52kPa was recorded for run 1 but a pressure of 193.40kPa was recorded for run 2, which is a 4.12kPa difference. Also, even though at 8mL, both runs showed the same value of 226.08, it does not necessarily mean that the value was accurate, it only shows precision. Furthermore, even though the average of both runs were taken, that is not enough runs to diminish the effect/chance of outliers.Therefore, the last source of error is not acquiring enough data, more runs should have been performed to improve accuracy.

Conclusion:

In conclusion, the experiment proves Boyle's Law PV=C where C is a constant. It was calculated to be 1828.59 and calculated to be 2070 from the graphing software's curve of best fit. As the volume decreases, the pressure increases inversely to the exponent of one. Not all points were on the curve of best fit due to some experimental errors as well as the fact that gases in the real world do not behave ideally. However, the points were accurate enough and clearly represented a relationship hence Boyle's was successfully validated.

Aisha Khalid

Verification of Boyle's Law   Date 13 sep. 2017

Purpose: To validate Boyle's Law by investigating the relationship between the pressure and volume of a confined gas.

Hypothesis: Pressure and volume are inversely porportional if temperature is constant $P \propto \frac{1}{V}$ $PV = nRT$

~~Procedure~~ Materials:
- LabQuest 2
- Vernier Gas Pressure Sensor
- 20mL gas syringe
- USB key

Procedure:
1) Connect the gas pressure sensor to LabQuest 2
2) Set up the LabQuest 2 by choosing a new file and change the mode to "events with entry"
3) Choose a part of the syringe plunger to line up with the volume markings
4) Pull back syringe to the ~~20~~ 20 mL marking
5) Lock syringe tip into the pressure sensor
~~6) Push the syringe plunger and note down pressure data from LabQuest 2~~
7) For the event names of LabQuest write 17, 14, 11 ~~[illegible]~~ in three colums and set the unit to mL
8) ~~Push the syringe to the first marker (17mL)~~. After the pressure stabilizes press keep and enter your volume + 0.8. then select OK and note down observations
9) Push the syringe down 2mL and repeat step 8. Keep repeating for more increments. Pull plunger back to 20mL and note again

Date

10. Stop Data collection
11. Decide which measurement of the original volume to keep by looking at plotted points
Remove one not needed
12. Tap Analyze and choose Curve Fit

Observations: Data Table

Indep variable Volume (mL)	Dependent Variable Pressure (kPa)	
20.	101.50	100.25
18.	112.05	112.02
16.	126.31	125.29
14.	142.55	142.30
12.	166.39	163.96
10.	197.52	193.40
8.	226.08	226.08
20.	101.48.	

Jehandar