Verification of Gas Laws

Disala de Silva - 030007241

Course: CHM1311B

Professor: Dr. Rashmi Venkateswaran

TA: Lixuan Ren

Tuesday September 11th 2018

Introduction

The first gas law was discovered by Robert Hooke and Robert Boyle who further went on to develop Boyle's law. This was discovered using a glass tube with mercury to see the variation of pressure on a fixed weight. While discovering this, he discovered that the pressure multiplied by the volume is a constant. However, this law is only applicable for ideal gasses and when the temperature is kept at a constant. This experiment will prove this law using a syringe and gas pressure sensor to validate Boyle's theories. Charles' law was actually discovered by Joseph Louis Gay-Lussac, but his discovery was credited to Jacques Charles for his prior work in the previous century. The law states that volume of an ideal gas increases at the rate temperature does on the Kelvin scale. Avogadro's law simply states that the number of moles of a substance directly correlates with the volume of the ideal gas.

Ideal Gas Law

$$pV = nRT$$
$$where\ R\ =\ 8.134462\ J/mol\ \cdot k, T =\ temperature, pressure, n = moles\ and\ V = volume$$

The Ideal Gas Law consists of three different gas Laws: Boyle's Law, Charles' Law and Avogadro's Law. All three are explained below.

Boyle's Law

$$P1V1 = P2V2$$
$$where\ V = volume\ and\ P = pressure$$

Charles' Law

$$V1/T1\ =\ V2/T2$$
$$where\ V = volume\ and\ T = temperature\ in\ kelvin$$

Avogadro's Law

$$V1/n1\ =\ V2/n2$$
$$where\ V = volume\ and\ n =\ the\ number\ of\ moles$$

Combined Gas Law - This is a combination of Boyle's and Charles' Law.

$$(P1V1)/T1 = (P2V2)/T2$$
$$where\ P = pressure, V = volume\ and\ T = temperature$$

Materials Required

125 mL Erlenmeyer Flask
1L or 600mL Beaker
Rubber Stopper with hole
Digital Thermometer
Ice Water Bath
Extension Clamp
LabQuest 2
Vernier Gas Pressure Sensor
20 mL Gas Syringe
USB Flash Drive

Verification of Charles' Law

Procedure

As described in the lab manual. (L'Engle, 1983)

Take Note: Instead of measuring the temperature of the air inside the flask, measure the water temperature. Both temperature values; T_1 and T_2 should be taken as noted below in *Table 1*.

Data and Analysis

Table 1. Data obtained in Verification of Charles' Law

Initial Water Temperature in Beaker	21.8℃
Final Water Temperature in Beaker (T_1)	99.4℃
Ice Bath Water Temperature (T_2)	4.0℃
Initial Air inside Flask (V_1)	145 mL
Water Inside Flask after cooling (V_{cw})	48 mL
Final Air Inside Flask (V_2)	97 mL

Solving for V_2

$$V2 = V1 - Vcw = 145mL - 48mL = 97mL$$

Converting temperatures to Kelvin

$$T1 = 99.4℃ + 273.15 = 372.55\mathrm{K}$$
$$T2 = 4.0℃ + 273.15 = 277.15\mathrm{K}$$

To prove Charles' Law one must now calculate the results using the values through the process of the lab.

$$V1/T1 \;=\; V2/T2$$
$$145mL/372.55\mathrm{K} \;=\; 97mL/277.15\mathrm{K}$$
$$0.39210mL/\mathrm{K} = 0.34999mL/\mathrm{K}$$

$percent\ error = ([(V1/T1) - (V2/T2)]/(V1/T1)) \times 100\%$
$percent\ error = ([(145mL/372.55\mathrm{K}) - (97mL/277.15\mathrm{K})]/(145mL/372.55\mathrm{K})) \times 100\%$
$percent\ error = ([(0.39210mL/\mathrm{K}) - (0.34999mL/\mathrm{K})]/(0.39210mL/\mathrm{K})) \times 100\%$
$percent\ error = ((0.04211mL/\mathrm{K})/(0.39210mL/\mathrm{K})) \times 100\%$
$percent\ error = (0.107396mL/\mathrm{K}) \times 100\%$
$percent\ error = 10.73961\%$

Proving Charles' Law Using the Retrieved Data

$$\frac{V1}{T1} = \frac{V2}{T2} + percent\ error \times \frac{V1}{T1}$$

If this equation is true, this proves that Charles' Law is correct.

$$0.39210mL/\mathrm{K} = 0.34999mL/\mathrm{K} + 10.73961\% \times \frac{0.39210mL}{\mathrm{K}}$$
$$0.39210mL/\mathrm{K} = 0.34999mL/\mathrm{K} + 10.73961\% \times \frac{0.39210mL}{\mathrm{K}}$$
$$0.39210mL/\mathrm{K} = 0.34999mL/\mathrm{K} + 0.042110011mL/\mathrm{K}$$
$$0.39210mL/\mathrm{K} \cong 0.392100011mL/\mathrm{K}$$

From this calculation one can see that the percentage plus the smaller value equals almost exactly the larger value obtained above. This proves Charles' Law.

Observations

Apart from the boiling water no further observations were made. The human eye does not have the ability to observe the changes occurring to the gases, therefore the data collected must be used as a way to interpret the outcome of this experiment.

Discussion

While conducting the lab it was clear there was a large amount of error associated with this experiment. The biggest reason for error were the measurements from flasks and graduated cylinders. They were all eyeballed and no decimal places were taken as all measurements were taken to the lowest point of accuracy. With this big source of error the lab was still completed and the results were very close to each other. This proves that Charles' Law was proved in the experiment.

Verification of Boyle’s Law

Procedure

As described in the lab manual. (L’Engle, 1983)

Data

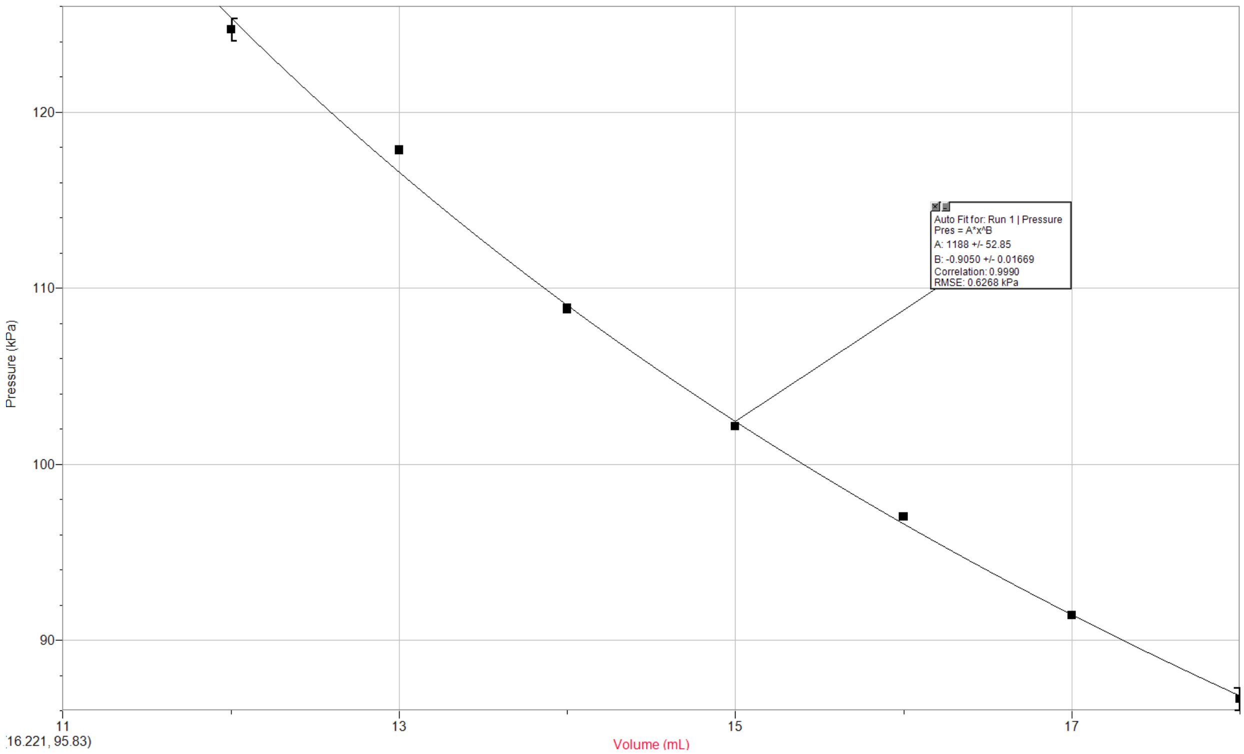
The plunger of the syringe was placed at 15 mL before the experiment was conducted. This allowed for easier movement of the plunger due to air pressure inside the syringe. Additionally 0.8 mL was added to each reading as there was volume of 0.8 mL inside the pressure sensor itself

The independent variable is the volume as because was the one that we could set on the syringe, whereas pressure was the result of the volume we made go to the plunger.

Table 2. Verification of Boyle’s Law: Volume (mL) vs. Pressure (kPa) obtained

Volume (mL)	Pressure (kPa)
12.8	124.70
13.8	117.86
14.8	108.81
15.8	102.19
16.8	97.02
17.8	91.43
18.8	86.67

Graph 1. Verification of Boyle's Law: Pressure (kPa) vs Volume (mL)



After putting the graph into *Logger Pro*, the software gave an equation of:

$$y = a \times x^{b}$$
$$where\ a = 1188\ \pm\ 52.85$$
$$and\ where\ b =\ 0.9050\ \pm\ 0.016697$$

The software also give a correlation coefficient of 0.9990 which proves that there is a very good correlation between the points and the curve of best fit. Initially this may not look like the actual Pressure (kPa) vs Volume (mL), however with further examination one can see that the scale is much larger than other graphs, forcing the curve to look less steep. Once this is taken into account it is comparable to many other Pressure (kPa) vs Volume (mL) graphs.

Discussion

While conducting the lab there was a big complication on how precise the syringe could be placed for the volume measurements. The plunger has a curved tip which does not allow for exact measurements and forces the lab conductor to approximate the volume inside the syringe. This causes a slight error and is shown by the data when it is graphed in *Logger Pro*.

Boyle's Constant Calculation

$$PV = k$$
$$k = (102.19kPa)\times(15.8mL)$$
$$k = 1614.602kPa \bullet mL$$

Pressure (kPa) multiplied by the Volume (mL) equates to the *k* value for the system. By using the formula, the obtained values in the lab process may be substituted into the equation so solve for the constant which correlates to the results of the lab. All the values give the exact same constant.

$$PxVx = k$$
$$PxVx = 1614.602kPa \bullet mL$$

The first and last measurements were taken to observe whether there was an error while measuring or for any other circumstances that may have affected the result of the measurement. The more trials conducted for each independent variable, the higher the accuracy of the lab may be.

Boyle's law requires the temperature of the surrounding gasses to remain constant. This was taken care of as the experiment was conducted inside a closed lab. However, as the room was crowded and multiple hot plates were on the temperature may have fluctuated and caused some error in the results. As the temperature remained fairly constant it is highly likely the results will have anything but minor errors.

Conclusion

After conducting the lab, both Boyle's Law and Charles' Law were proven. Boyle's law stated that pressure and volume of gases correspond inversely with each other when temperature is held constant and it was proven by the gas pressure inside the syringe. Charles' law stated that gases tend to expand when heated and it was proven by the volume change of the gasses inside the heated and cooled flask.

References

- L'Engle, M. (1983). Do I Dare Disturb the Universe? New York, 1–4

- Martin Silberberg, D. (2017). Chemistry: The Molecular Nature of Matter and Change With Advanced Topics. McGraw-Hill Education

- Study.com (2018). Combined Gas Law Definition Formula Example: Combined Gas Law: Definition, Formula & Example. Study.com. (linked)

Experiment #1 Sept 11th 2018

Verification of Gas Laws

Charles' Law: gases contract when they are cooled and expand when they are heated. Volume with respect to Temperature

Boyle's Law: gases contract when they are cooled and expand when they are heated. Volume with respect to Pressure.

Verification of Charles' Law Procedure:

1) Obtain clean 125 mL Erlenmeyer Flask. If it is not clean, rinse with 2-3 mL of Acetone and place in oven for 5 min.

2) Place rubber stopper in Erlenmeyer Flask and mark the bottom with a marker.

3) Fill large beaker with 2/3 tap water.

4) Place beaker on hot plate. Beware, the hot plate can burn you, take precautions.

5) Clamp Erlenmeyer Flask with an extension clamp and place in the large beaker as far down as possible without submerging the flask.

6) Turn on hotplate and boil the water. Monitor temperature of air inside the flask. Once water boils allow flask to sit for 6-7 minutes.

7) Prepare ice bath (below 6°C).

8) Use digital thermometer to determine the temperature of the ~~air~~ water in the ~~flask~~ beaker. Place finger over hole on stopper and remove flask by detaching the clamp. Do not touch flask as it has been in boiling water, very hot.

9) Keeping finger on the stopper, lower flask into ice bath with stopper facing down. Once mouth is submerged, remove finger. If air bubbles are present a restart of the experiment is required.

10) Flask should be submerged for 5-6 minutes until air inside equilibrates to water temperature.

11) Record ice bath temperature.

12) Raise or lower flask so flask matches water level.

13) When both levels are matched remove Flask after covering the hole with Finger.

14) Transfer water in Flask to a graduated cylinder and note volume as "Vew."

15) Fill Flask to mark previously drawn and transfer to a graduated cylinder and note this volume as "V".

16) Repeat experiment once, if time allows repeat twice.

Verification of Boyle's Law Procedure:

1) Connect gas pressure sensor to lab Quest 2. Turn on LabQuest 2 and choose "New" From the File Menu.

2) Move the plunger of a 20mL syringe to a chosen volume and decide which part of the tip of the plunger will line up on the volume mark.

3) Attach the 20mL syringe to the gas pressure sensor valve. Only turn the syringe 1/2 a turn to ensure the equipment does not get damaged.

4) On the LabQuest 2 meter screen, tap "Mode" and change the option to "Events with Entry".

5) Enter the Variable name and units, then select "Ok"

6) There is 0.8mL of space inside the sensor, so add 0.8mL to all volume readings

7) Start data collection, hold plunger at initial volume mark

8) After the pressure reading stabilizes, tap "Keep" and enter volume recorded plus 0.8mL from step 6.

9) Select "Ok" to continue.

10) Move plunger to change volume of air in the syringe and hold the plunger in place.

[signature]

11) Repeat Step 8

12) Continue performing step 10 and 8 consecutively at 6-8 different volumes.

13) For the final volume move the plunger back to the initial position mark.

16) Examine the plotted points on LabQuest 2 and carefully decide which of the two points at the same volume is better. Explain why in the report.

17) Tap the table icon (top of the screen). Choose the original data data point for volume that is to be removed by tapping it.

18) Open the menu by tapping on the word "table" and choose "Strike Through Data". Lines through the data show it has been removed.

19) Tap the "Graph" icon to return to the graph screen.

20) Tap "Analyze" and choose "Curve Fit" → for your variable.

21) Open the menu below Fit Equation and choose a function on your data.

22) Select "Ok" to return to the graph screen.

23) Repeat Steps 20-23 if another function may suite the graph better.

Charles Law Data

Time of Temperature Taken (minutes)	Temperature
0	21.8°C
1	24.5°C
2	27.9°C
3	33.4°C
4	36.3°C
5	
6	

Trial 1 { Initial Water Temperature : 21.8°C
Final Water Temperature : 98.9°C

TRIAL 2

T_2 = Ice Water Temp 4.0°C

Initial H_2O Temp : 21.8°C
T_1 = Final H_2O Temp : 99.4°C

H_2O in graduated cylinder V_{CW} = 48 mL
V_1 = 145 mL

$V_2 = V_1 - V_{CW} = 97 mL$
$V_2 = 97 mL$

[illegible]

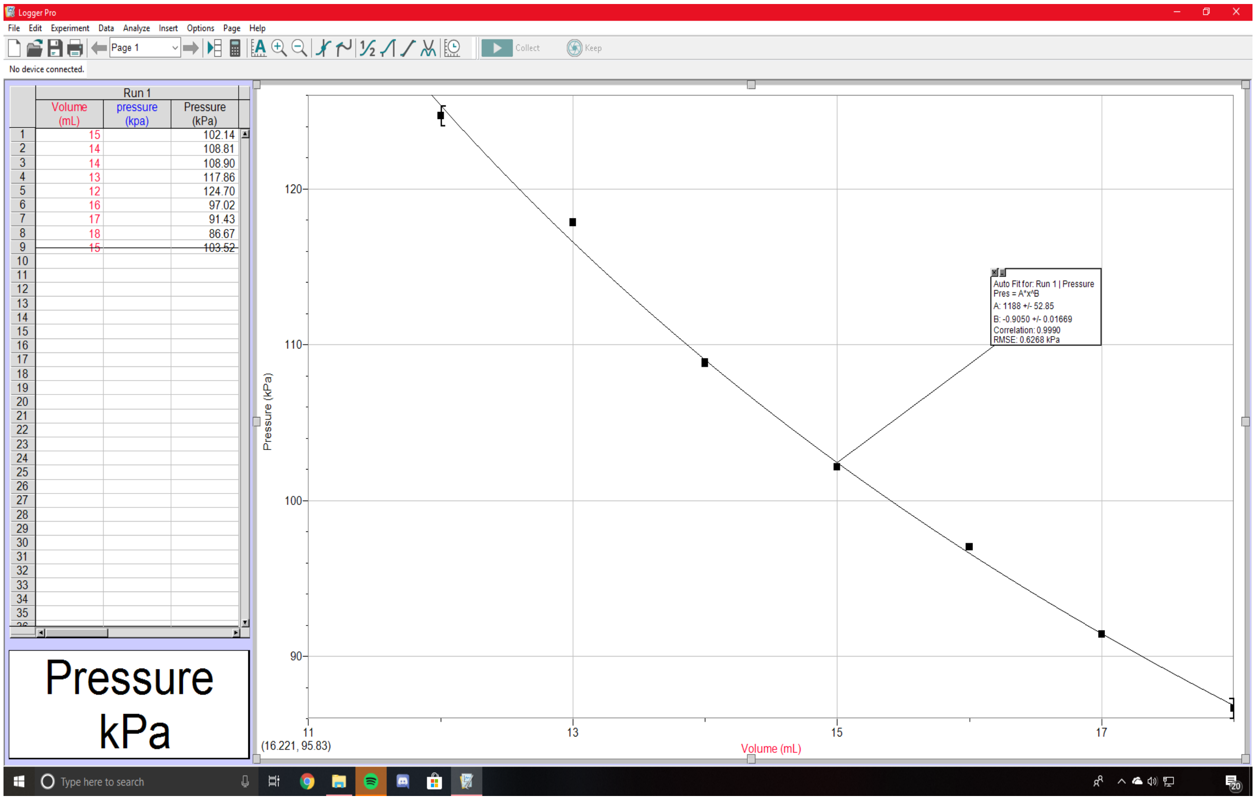
Boyle's Law Data

Volume (mL)	Pressure (kPa)	
12	~~126.87~~ →	126.69
13	~~126.32~~	117.53
14	~~117.27~~	110.81
15	~~111.09~~	102.69
16	96.88	
17	92.23	
18	86.56	
15 (#2)	103.59	

TRIAL 2

Volume (mL)		Pressure (kPa)	
12	+0.8	124.70	~~±0.8~~
13	+0.8	117.86	~~±0.8~~
14	+0.8	108.81	~~±0.8~~
15	+0.8	102.19	~~±0.8~~
16	+0.8	97.02	~~±0.8~~
17	+0.8	91.43	~~±0.8~~
18	+0.8	86.67	~~±0.8~~

* 0.8 added for volume inside pressure sensor


Logger Pro
File Edit Experiment Data Analyze Insert Options Page Help
Page 1
Collect
Keep
No device connected.
Run 1
Volume (mL)
pressure (kpa)
Pressure (kPa)
15 102.14
14 108.81
14 108.90
13 117.86
12 124.70
16 97.02
17 91.43
18 86.67
15 103.52
Pressure kPa
Auto Fit for: Run 1 | Pressure
Pres = A*x^B
A: 1188 +/- 52.85
B: -0.9050 +/- 0.01669
Correlation: 0.9990
RMSE: 0.6268 kPa
Pressure (kPa)
120
110
100
90
11
13
15
17
Volume (mL)
(16.221, 95.83)
Type here to search

Assessment Criteria for Planning the Boyle's Law Investigation
(to be completed BEFORE lab and given to TA)

TA Name:		Names of Students in Group:	a. Disala de Silva
			b.
		Date:	
Criteria:	Marks	Assessment	
	Possible	Self	TA
1. Identify the problem and state it clearly in a way that can be tested.	1	1	
2. Use proper apparatus, techniques and safety precautions.	1	1	
3. Materials are easily available.	1	1	
4. Plan to vary only one independent variable at a time.	1	1	
5. Controls on other variables are clearly stated.	1	1	
6. Measurement errors are minimized by appropriate procedures or apparatus.	1	1	
7. The methods are clear enough to be followed by other students.	1	1	
8. No invalid assumptions are made.	1	1	
9. Reagents that need accurate measurement are identified.	1	1	
10. Lab trials are stated.	1	1	
11. Repeats are stated.	1	1	
12. Chemistry vocabulary is used correctly.	1	1	
13. Limitations of the experimental design are described.	1	1	
TOTAL:	13	13	

12....Experiment 1