

“Do I Dare Disturb the Universe”: Verification of Gas Laws

Jasmine Foreman

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Medical or other Acceptable Document: NA

Change of Lab Day Form: NA

Change of Lab Section Form: NA

Late Pass: NA

Procedure – Charles' Law:

As outlined in lab manual. (1)

Procedure – Boyle's Law:

1. Connect Lab Pressure Sensor to LabQuest2
2. Open a new file
3. Pull syringe to 20 mL mark
4. Connect tip of syringe to valve of gas pressure sensor. Turn a half rotation to lock into place
5. Measure pressure at 20 mL and collect data on LabQuest2 (ensuring you add 0.8 mL to the indicated value on syringe)
6. While leaving the syringe attached to pressure sensor, decrease volume by 4 mL
7. Record data until a value of 4 mL is reached. Once reached record pressure at this value twice. Then continue recording data by adding 4 mL each time until 20 mL is reached.

Discussion:

Charles' Law

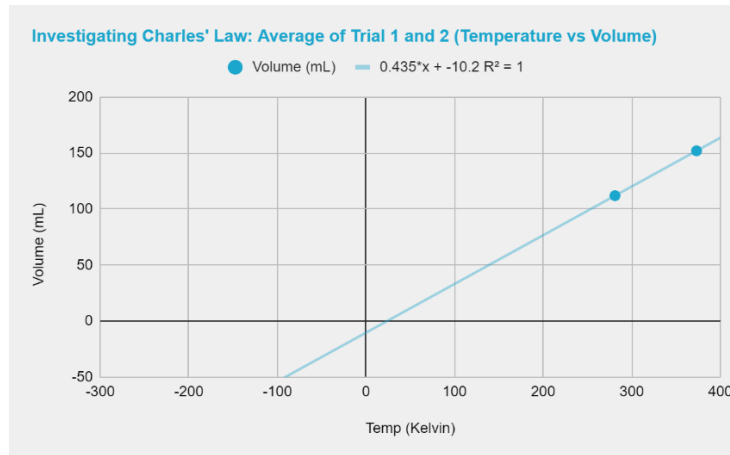
Charles' Law describes a proportional relationship between the volume of a gas and the absolute temperature of a gas when pressure is kept constant. (2) Thus, the independent variable is the temperature, the dependent variable is the volume, and the pressure becomes the control variable. The purpose of this experiment was to test this theory by measuring the volume of a gas at two temperature extremes; 100° C (373.15k) and as close to the freezing point of water as possible (0° C). Although, the freezing point of water could not be reached due to the nature of the experiment. By measuring the volume of the gas at these two extremes it can be determined whether a linear relationship exists between these two variables as stated in Charles' Law. (1) A proportionality constant (described as "k" for the purpose of this experiment) can be determined for a given sample of gas. (2)

Table 1: Average of Trials One and Two for Experimentally Determining Validity of Charles' Law

Volume (mL)	Temperature (° C)	Temperature (K)	V/T (mL/° C)	V/T (mL/K) (Proportionality Constant k)
152	100	373.15	1.52	0.41
112	8	281.15	14	0.40

As shown in *Table 1*, the proportionality constant was calculated to be reasonably consistent at the two temperature extremes. The 2.2% error could be explained by unavoidable sources of error as followed; The stopper inserted into the Erlenmeyer flask is neither airtight nor completely immobile, this could have allowed for a variation of pressure within the flask accounting for the inconsistency. The thermometer used to measure the temperature of the ice bath is only accurate to one significant figure and requires accurate reading by the individual performing the experiment. When submerging the hot Erlenmeyer flask into the ice bath the air within the flask comes in contact with the water rushing in to decrease the volume. When this occurs, there is the possibility for the air to become dissolved within the water again varying pressure and modifying results. (3)

Figure 1: Average of Trial 1 and 2 - Temperature vs Volume

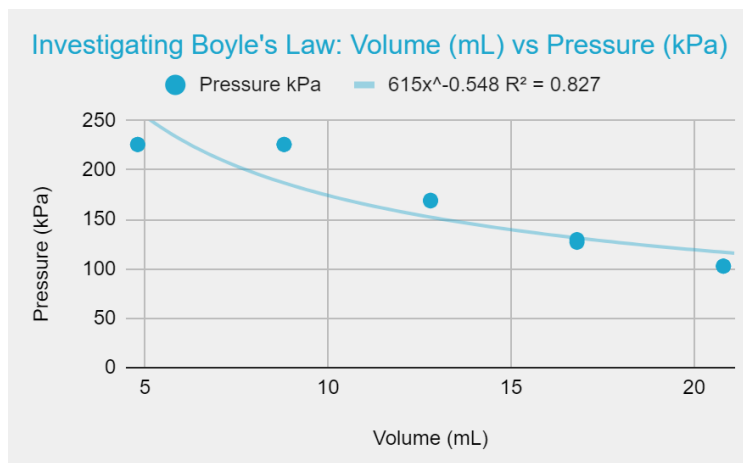


As the temperature of the gas increases the volume does correspondingly. Thus, as the temperature of the gas decreases, the volume approaches zero. (3) This plays a key role in understanding Kinetic Molecular Theory which attributes the temperature of a gas to the average kinetic energy of its particles. (4) The greater kinetic energy particles have, the more space they require. Accordingly, as the kinetic energy of a group of particles decreases the less space they will occupy. Shown clearly in this experiment, the decrease in kinetic energy of gas particles causes the decrease in volume of the gas without altering the pressure or number of gas particles.

The interpretation of temperature in units of Kelvin is critical to understanding the implications of Charles' Law; as zero on the Kelvin scale represents the stop of all molecular motion. (2) In theory, when graphed a zero temperature should result in a zero volume. Of course, this is not possible as a gas would condense to a liquid before reaching this point. (2) Additionally, this theory only applies to gasses that adhere to the conditions of an "ideal gas". (1) Conditions that are only met at extremely low pressure or high temperatures. The variation of the results obtained, and the expected graph could be accounted for by the conditions of an ideal gas not being met as well as the possible sources of error stated above.

Boyle's Law

Figure 2: All Data used to Describe Boyle's Law – Volume Vs. Pressure



Boyle's Law describes an inversely proportional relationship between the volume and the pressure of a given gas. The original law $P_1V_1=P_2V_2$, can be rearranged to describe the pressure of a gas as a function of its volume, $P_1=k/V$, where k is a constant found for a given sample of gas. K can then be found by rearranging the formula to $k=P_1V_1$ (calculated values of K for varying volumes are found in the appendix). As seen above in *Figure 2*, the inversely proportional relationship between volume and pressure was determined experimentally.

For this experiment, the independent variable was volume and the dependent variable was the pressure. For the relationship of these two variables to be tested accurately the gas must be kept at a constant temperature, have a constant amount of gas particles, and meet the requirements of an ideal gas (low pressure or high temperature). The entirety of this experiment was performed consistently at room temperature and therefore met this requirement. Although slight fluctuations in temperature are possible, it is not likely this greatly impacted the results. The amount of gas kept in the syringe was kept constant throughout the experiment as the syringe remained attached to the pressure sensor. The amount of gas contained in the syringe could have varied slightly due to effusion. An escape of gas would have decreased the pressure in the syringe and had a greater impact as the total pressure of the syringe increased.

A gas that meets the requirements of an ideal gas should have a relationship $(PV)/(RT)=1$. When the data collected for the investigation of Boyle's law was inputted into this equation at a fixed temperature (temperature has no effect so long as its constant), the values varied at increasing intervals away from 1 as the pressure increased. (6) As the pressure of the gas inside the syringe increased the variation between the real gas and the ideal gas law relationships also increased, making the relation of Boyle's Law less and less accurate. (1) *Figure 2* shows a relationship that is inversely proportional however, the line of best fit doesn't perfectly match the expected graph indicating major sources of error in the experiment.

When conducting this experiment volumes were recorded at decreasing intervals and then recorded again using the same gas sample at increasing intervals. The multiple data sets for each volume allows for more accuracy in the results should there be an issue with the sensor or other possible variations. It also allows for the determination of whether large amounts of gas have escaped from the syringe when pressure is increased. It is shown in the collected results that this is not the case. The pressure remained somewhat consistent for both values of volume. However, it is possible that just as gas escaped, it could have re-entered the syringe via effusion. (5)

Conclusion:

Overall, the linear proportionality of temperature and volume as stated in Charles' Law was clearly displayed in this experiment with a percent error of 2.2%. The investigation of Boyle's law determined an inversely proportional relationship between pressure and volume. However, the line of best fit found for the data collected did not perfectly match the expected relationship of $y=1/x$.

Reference(s):

1. "Do I dare Disturb the Universe", Verification of Gas Laws, Lab Manual

- Libretexts. (2019, June 5). Gas Laws. Retrieved from [https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Book:_Introductory_Chemistry_\(CK-12\)/06:_The_Periodic_Table](https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Book:_Introductory_Chemistry_(CK-12)/06:_The_Periodic_Table)
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- Kinetic molecular theory examples. (n.d.). Retrieved from https://www.keyword-suggest-tool.com/search/kinetic_molecular_theory_examples/
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- Neth, E. J., Flowers, P., Theopold, K., Langley, R., & Robinson, W. R. (2018). *Chemistry: atoms first*. Houston, TX: OpenStax.

Appendix:

Raw Data:

Additional Data, Charles' Law

Trial	Volume (mL)	Temperature (° C)	Temperature (K)	V/T (mL/° C)	V/T (mL/K) (Proportionality Constant k)
Trial 1	152	100	373.15	1.52	0.41
	121	6	279.15	20.2	0.43
Trial 2	152	100	373.15	1.52	0.41
	103	10	283.15	10.3	0.36
Average	152	100	373.15	1.52	0.41
	112	8	281.15	14	0.40

Additional Graphs, Charles' Law

Not applicable.

Sample Calculations, Charles' Law

Calculation 1:

$T_1 = 100\text{ }^\circ\text{C}$ or 373.15 K

$V_1 = 152\text{ mL}$

$T_2 = 6\text{ }^\circ\text{C}$ or 279.15

$V_{cw} = 31\text{ mL}$

$V_2 = V_1 - V_{cw}$

$V_2 = 152\text{ mL} - 31\text{ mL}$

$= 121\text{ mL}$

$V_1/T_1 = V_2/T_2$

Left Side: $= (152\text{ mL}) / (100\text{ }^\circ\text{C})$

$$= 1.52 \text{ mL}/^{\circ} \text{C}$$

$$= (152 \text{ mL}) / (373.15 \text{ K})$$

$$= 0.407 \text{ mL/K}$$

Right Side: $= (121 \text{ mL}) / (6^{\circ} \text{C})$

$$= 20.2 \text{ mL}/^{\circ} \text{C}$$

$$= (121 \text{ mL}) / (279.15 \text{ K})$$

$$= 0.433$$

Calculation 2:

$$\% \text{ Error} = \left(\frac{(V_1/T_1) - (V_2/T_2)}{(V_1/T_2)} \right) \times 100\%$$

$$= \left(\frac{((152/373.15) - (112/281.15))}{(152/373.15)} \right) \times 100\%$$

$$= 2.2\%$$

Additional Data, Boyle's Law

Volume (mL)	Pressure kPa	K=PV (mL * kPa)	Ideal Gas PV/RT=, T=298.15, R=8.314
20.8	102.63	2134.704	0.86
16.8	126.8	2130.24	0.86
12.8	168.73	2159.744	0.87
8.8	225.89	1987.832	0.80
4.8	225.87	1084.176	0.44
4.8	225.9	1084.32	0.44
8.8	225.89	1987.832	0.80
12.8	169.37	2167.936	0.87
16.8	129.51	2175.768	0.88
20.8	102.61	2134.288	0.86
Average K=		1904.684	

Additional Graphs, Boyle's Law

Not applicable.

Sample Calculations, Boyle's Law

Calculation 1:

$$K = PV$$

$$= (102.63 \text{ kPa})(20.8 \text{ mL})$$
$$= 2134.704 \text{ kPa}\cdot\text{mL}$$

Calculation 2:

$$= PV/RT$$

$$= (20.8 \cdot 102.63) / (8.314 \cdot 298.15)$$

$$= 0.86$$

Assessment Criteria Sheet

Rubric for Correction of Experiment 1

Procedures (1+3)	Superior protocol that tests data, minimizes error and includes safety	Good protocol that tests data, minimizes error and includes safety	Acceptable protocol that tests data, minimizes error and includes safety	Partial graphs		Poor protocol that tests data, minimizes error and includes safety
				Complete graphs	Poor/no graphs	
Graphs (2)	Clear, complete graphs	Complete graphs	Explanations are vague; connections to observation/data unclear; comparisons or ties to theories poorly explained	A few important points missing	Many important points missing	no discussion
Discussion (6+6)	<i>As outlined in Worksheet Guidelines:</i> Clear explanation of results based on observation and data; reasonable explanation for errors; comparison between trials; answers to all questions; ties to theory clearly shown; tables and graphs appropriately titled containing all required information and properly placed.	Explanation of results; some connection to observation/data; explanation of errors; some comparisons; answers to some questions; some ties to theory	Results somewhat evident.	Results not evident/missing.		
Conclusion (1)	Results clearly stated.	At least 1 peer-reviewed reference (1)				
Calculations (2+2)	ONE complete set of calculations shown neatly	Some calculations shown neatly	No calculations			
Grade for Assessment Criteria (6)						
Total (30)						

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Sept 12th 2019

Charles' Law Observatio Data #1

$$T_2 = 6^\circ\text{C}$$

$$V_{cw} = 31\text{ mL}$$

$$T_1 = 100^\circ\text{C}$$

$$V_1 = 152\text{ mL}$$

$$V_2 = V_1 - V_{cw}$$

$$V_2 = 152 - 31$$

$$= 121\text{ mL}$$

$$V_1 = 50 + 50 + 50 + 2$$

$$= 152\text{ mL}$$

Boyle Law

Boyle Law Data

Volume (mL)	Pressure kPa
20.8 mL	102.87 kPa
46.8 mL	
12.8 mL	
8.8 mL	
41.8 mL	
8.8 mL	
12.8 mL	
16.8 mL	
20.8 mL	

Volume (mL)	Pressure kPa
20.8	102.82 kPa
16.8	62

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Charles' Law #2

$$T_2 = 10^\circ\text{C}$$

$$V_{cw} = 49\text{ mL}$$

$$T_1 = 100^\circ\text{C}$$

$$V_1 = 152\text{ mL}$$

$$V_2 = V_1 - V_{cw}$$

=

Haley

Jasmine Foreman
September 12th 2019

Verification of Boyle's Law ($P_1V_1 = P_2V_2$)

Independent Variable - Volume (mL)

Dependant Variable - pressure (kPa)

Procedure

1. Connect Lab pressure sensor to Labquest 2, choose New File
2. ~~Connect syringe~~ pull syringe to 20 mL mark
3. Connect to Valve of Gas pressure Sensor, Lock into place
4. Turn on data collection mode
5. Collect data: tap "keep" and enter Volume 10.8
6. Change Volume in Syringe to ~~10~~ mL and repeat of last recorded value
7. Repeat steps 3-6, until volume reaches 4 mL
8. Repeat steps 3-6, instead increasing volume until back to 20 mL
9. STOP Data Collection
 * Do not disconnect syringe
10. Remove unwanted data (choose better of 2 points)
11. Graph data and analyze Curve Fit

Weight 200g
Sept. 12 2019

Assessment Criteria for Planning the Boyle's Law Investigation
 (print and paste in your lab notebook before coming to lab)

TA Name:	Wei Yi Zhou	Names of Students in Group:	a. Jasmine Foreman
			b. Roxana Shamsi
		Date:	Sept 12 th 2019
Criteria:	Marks Possible	Assessment	
		Self	TA
1. Plan to vary only one independent variable at a time.	1	1	1
* 2. Controls on other variables are clearly stated.	1	1	1
3. Measurement errors are minimized by appropriate procedures or apparatus.	1	1	1
4. The methods are clear enough to be followed by other students.	1	1	1
5. Trials and replicas are stated.	1	1	1
* 6. Limitations of the experimental design are described.	1	1	1
TOTAL:	6	6	6

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Boyle's Law Data

<u>Volume (ml)</u>	<u>Pressure</u>
20.8	102.63
16.8	126.80
12.8	168.73
8.8	225.89
4.8	225.87
4.8	225.89
8.8	225.89
12.8	169.37
16.8	129.51
20.8	102.61

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Sept. 12. 2019.