

Work Sheet – Experiment 1

Experiment Title:

Experiment 1: Verification of Gas Laws

Author(s) Name(s):

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Submitting Author's Partner:

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TA (Demonstrator)'s Name:

Nan Liu

Date Experiment Performed:

Tuesday, September 10th, 2019

Date Experiment Submitted:

Tuesday, September 17th, 2019

(The report for Experiment 1 does not require an Introduction)

Attach here (if required, indicate the appropriate document(s)):

Medical or other Acceptable Document: _____

Change of Lab Day Form: _____

Change of Lab Section Form: _____

Late Pass: _____

Procedure – Charles’ Law:

As described in the lab manual [1].

Procedure – Boyle’s Law:

In the Boyle’s Law part of the experiment, we had to create our own procedure to help verify the law.

Our Procedure, step by step:

- Plug in Gas pressure sensor to LabQuest 2.
- Align the first ring of the syringe to **15 mL**, then put the syringe in the gas pressure sensor. Then record the pressure (in kPa).
- Then, align the first ring again of the syringe but this time to a different volume, **9 mL**. Record the pressure (in kPa).
- Align the first ring again of the syringe to a different volume, **20 mL**. Record the pressure (in kPa).
- Align the first ring again of the syringe to a different volume, **17 mL**. Record the pressure (in kPa).
- Align the first ring again of the syringe to a different volume, **5 mL**. Record the pressure (in kPa).
- Align the first ring again of the syringe to a different volume, **18 mL**. Record the pressure (in kPa).
- Repeat this procedure a second time (Do procedure twice).

Discussion:

Charles’ Law

Charles’ law describes that gases contract when cooled and expand when heated in a fixed pressure [1]. In other words, at a constant pressure, the law states that the volume of any sample of gas is directionally proportional to the temperature in Kelvin. Therefore, the equation for Charles’ law can be described as:

$V/T = K$, where **K** is a constant, **V** is the volume, and **T** is the temperature (see the general graph of Charles’ law under “Additional Graphs, Charles’ Law” header in Appendix below)

To help verify this law, we followed the procedure given to us in the lab manual. While doing Trial 1 of the Charles’s law in a fixed pressure, we recorded the data we received and organized it in a table to observe our results clearly. This is the table that we made...

Trial 1 Table:

T1 – <i>Temperature of boiling water (degrees Celsius)</i>	T2 – <i>Temperature of ice bath (degrees Celsius)</i>	T1 – (in Kelvin)	T2 – (in Kelvin)	V1 – initial volume of air in flask (mL)	V2 – final volume after cool down (mL) <i>*was found by V1 - Vcw</i>	Vcw – (mL)
100	0.5	373.15	273.65	125.0	98.0	27.0

In this set of data, and we can compare the initial volume and final volume and see that the volume of the gas has decreased after the cool down (it went from 125.0 mL to 98.0 mL). This verifies the definition of the law that gases expand when heated and contract when cooled.

Additionally, we were asked to repeat the procedure of the Charles's law one more time, so we also recorded our Trial 2 data and organized it in a table to observe our data. This is the table that we made for it...

Trial 2:

T1 – <i>Temperature of boiling water (degrees Celsius)</i>	T2 – <i>Temperature of ice bath (degrees Celsius)</i>	T1 – (in Kelvin)	T2 – (in Kelvin)	V1 – initial volume of air in flask (mL)	V2 – final volume after cool down (mL) <i>*was found by V1 - Vcw</i>	Vcw – (mL)
100	0.5	373.15	273.65	122.0	89.0	33.0

In this set of data, we can observe that the data is slightly different than the first set of data, but it also verifies Charles' law. As the results are very similar, it also shows that the final volume of the gas has decreased after the cool down (it went from 122.0 mL to 89.0 mL) which verifies the definition of the law.

Additionally, if we look at the calculations we made (see "Sample Calculations, Charles' law" under Appendix), we calculated an average constant for each of the volumes and temperature and found the averages of the initial K and final K for both trials. The calculated values were not the same but were very close to each other (Trial 1 K = 0.3249, Trial 2 K = 0.3581). We also calculated the percent errors (which is also found in the Appendix) for both trials, which is why the two are not exactly the same. However, since we were able to find constant values and they are very close to each other, this also verifies Boyle's law that $V/T = K$.

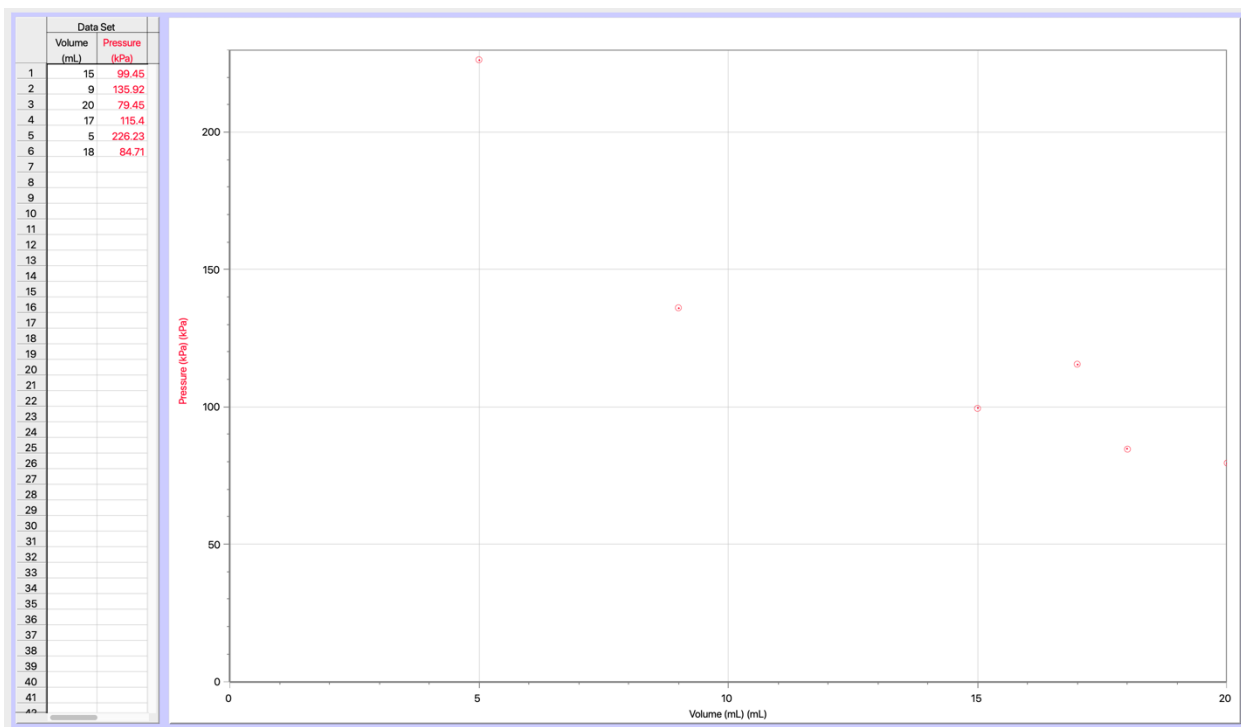
Boyle's Law

Boyle's law says that a gas' pressure increases as the occupied volume of the gas decreases. This is when the temperature of the trapped gas remains constant. In other words, the pressure of a gas is inversely proportional to its volume. [3] Therefore, the equation of Boyle's law can be described as:

$PV = K$, where K is a constant, P is the pressure, and V is the volume (see the general graph of Boyle's law under "Additional Graphs, Boyle's Law" header in Appendix below)

To help verify this law, we created our own procedure to follow. While doing Trial 1 of our Boyle's law procedure, we recorded the data we got and organized it in a graph using LoggerPro to observe our results clearly. This is the Trial 1 graph that was made using LoggerPro...

Trial 1 Graph:

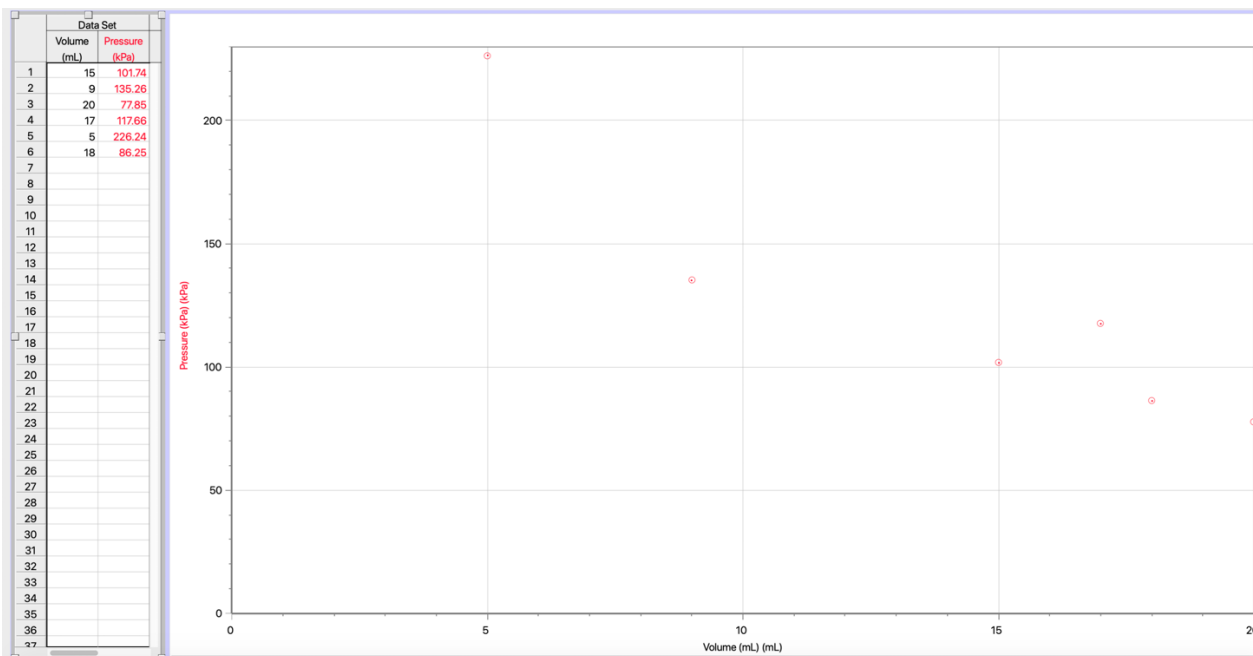


In this graph, we have 6 different volumes in mL which each corresponds to a pressure in kPa. The independent variable is the volume of the gas, and the dependent variable is the pressure of the gas. The pressure of the gas depends on the volume of the gas, and looking at this graph, we can observe that as the volume of the gas increases, the pressure of the gas decreases and vice versa. Through this observation, we just verified Boyle's law that that a gas' pressure increases as the occupied volume of the gas decreases when it is at a fixed temperature.

Also, if we compare this graph that we made to the general graph of Boyle's law (see the general graph of Boyle's law under "Additional Graphs, Boyle's Law" header in Appendix below), our graph and experiment can confirm that general graph as the two graphs are similar looking. There is, however, an outlier in our graph, which is the 17 mL part, but that is most likely a record error on our part.

When we repeated our procedure the second time, we also recorded our data and organized it in a graph to observe it. Here is the graph for Trial 2 that was made from LoggerPro...

Trial 2 Graph:



In this graph, we can observe that it's similar to the graph that we have from the first trial. As the volume decreases in the graph, the pressure increases, therefore verifying Boyle's law also.

Additionally, if we look at the calculations we made (see "Sample Calculations, Boyle's law" under Appendix), we calculated an average constant for each trial data. Both were very close to each other (Trial 1 average = 1486.96, Trial 2 average = 1497.39). This verifies Boyle's law that $PV = K$.

Conclusion:

In conclusion, this experiment helped us successfully verify Charles' and Boyle's law and is shown through our data tables and graph. In our Charles' law procedure, we observed that the volume of the gas has decreased after cooling which verifies the law. In our Boyle's law procedure, we graphed our data and saw that as the volume of the gas decreases, the pressure increases, which also verifies the law. In addition, we also verified the laws as we were able to calculate K values with our obtained data using the equations of the gas laws.

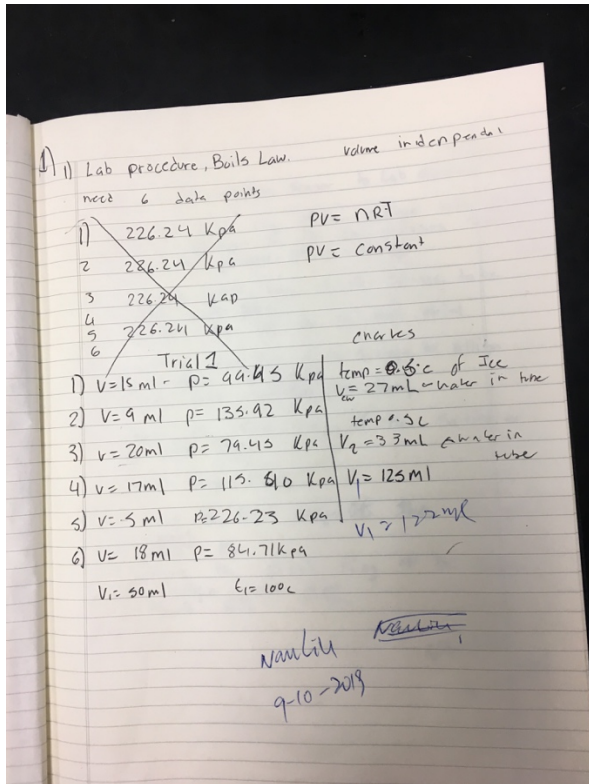
Reference(s):

- [1] Dr. Rashmi Venkateswaran, "Verification of Gas Laws: Lab Manual", Experiment 1, Pages 6 – 8, (2019).

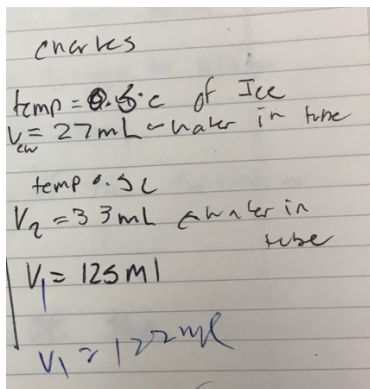
- [2] Martin Silberberg, "Chemistry: The Molecular Nature of Change and Matter", McGraw Hill Education, Pages 154- 159, (2016).
- [3] John B. West, "The original presentation of Boyle's Law", American Physiological Society, <https://www.physiology.org/doi/full/10.1152/jappl.1999.87.4.1543>, (1999).

Appendix:

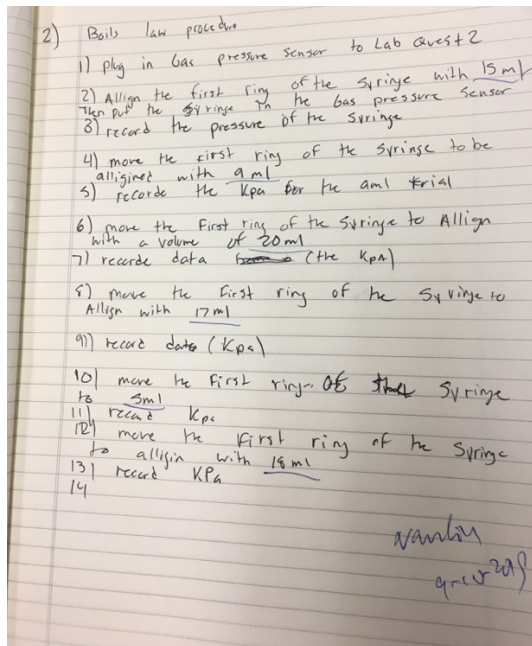
Raw Data:



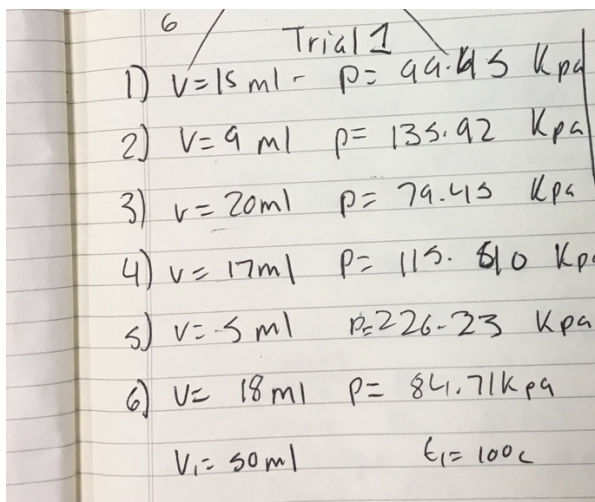
Charles's Law Trial 1 and 2:



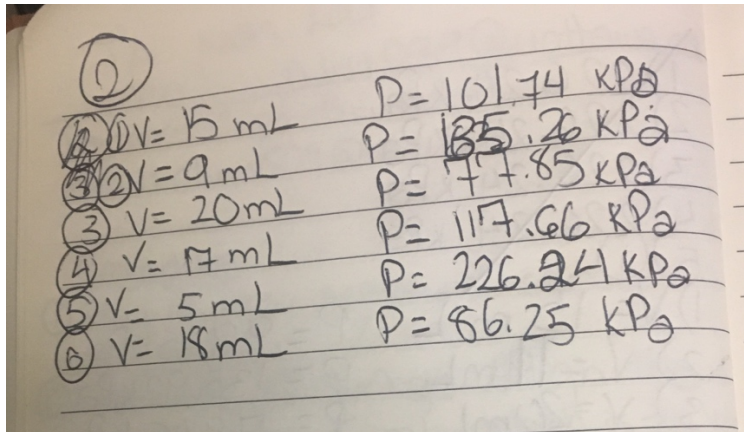
Boyle's Law procedure we wrote from our Lab notebook:



Boyle's Law Trial 1:



Boyle's Law Trial 2:



A photograph of a handwritten notebook page showing Boyle's Law data. The page is numbered 2 in a circle. It lists six trials with volume (V) and pressure (P) values. The pressure values are calculated based on Boyle's Law (P1V1 = P2V2).

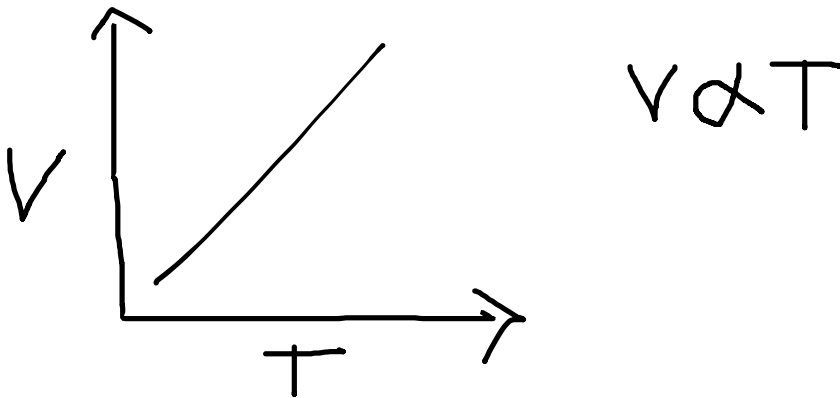
Trial	Volume (V)	Pressure (P)
1	15 mL	101.74 kPa
2	9 mL	135.26 kPa
3	20 mL	77.85 kPa
4	17 mL	117.66 kPa
5	5 mL	226.24 kPa
6	18 mL	86.25 kPa

Additional Data, Charles' Law

Not applicable.

Additional Graphs, Charles' Law

Since Charles' law describes that the volume of a gas is directionally proportional to its temperature [2] (its equation can be $V/T = K$), its general graph is:



Sample Calculations, Charles' Law

Trial 1:

T1 Temperature of boiling water (degrees Celsius)	T2 Temperature of ice bath (degrees Celsius)	T1 (in Kelvin)	T2 (in Kelvin)	V1 initial volume of air in flask (mL)	V2 final volume after cool down (mL) V1 – Vcw	Vcw (mL)
= 100	= 0.5	= 100 + 273.15 = 373.15	= 0.5 + 273.15 = 273.65	= 125.0	= 125.0 – 33.0 = 98.0	= 33.0

$$\frac{V}{T} = K, \quad \frac{V1}{T1} = \frac{125.0}{373.15} = \mathbf{0.3350} \quad \frac{V2}{T2} = \frac{98.0}{273.65} = \mathbf{0.3581}$$

Trial 2:

T1 Temperature of boiling water (degrees Celsius)	T2 Temperature of ice bath (degrees Celsius)	T1 (in Kelvin)	T2 (in Kelvin)	V1 initial volume of air in flask (mL)	V2 final volume after cool down (mL) V1 – Vcw	Vcw (mL)
= 100	= 0.5	= 100 + 273.15 = 373.15	= 0.5 + 273.15 = 273.65	= 122.0	= 122.0 – 27.0 = 89.0	= 27.0

$$\frac{V}{T} = K, \quad \frac{V1}{T1} = \frac{122.0}{373.15} = \mathbf{0.3249} \quad \frac{V2}{T2} = \frac{89.0}{273.65} = \mathbf{0.3252}$$

$$\text{Average of } K = \frac{0.3350 + 0.3581 + 0.3249 + 0.3252}{4} = \mathbf{0.3358}$$

$$\text{Percent error for Trial 1} = \frac{K1-K2}{K1} (100) = \frac{0.3350-0.3581}{0.3350} (100) = \mathbf{-6.900\%}$$

$$\text{Percent error for Trial 2} = \frac{K1-K2}{K1} (100) = \frac{0.3249-0.3252}{0.3249} (100) = \mathbf{-0.092\%}$$

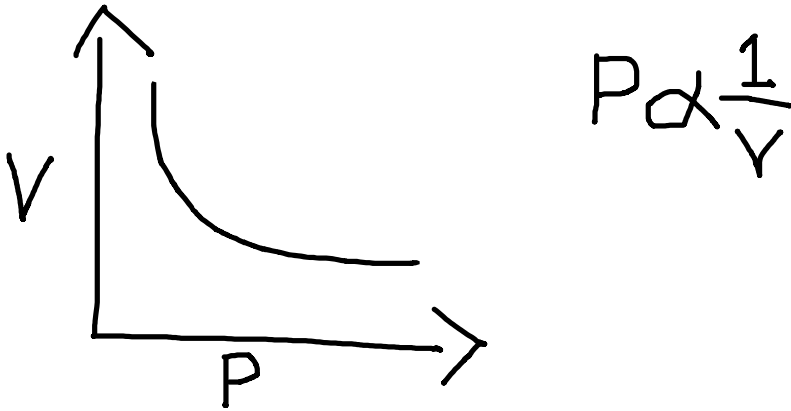
(Calculations explained and mentioned in discussion)

Additional Data, Boyle's Law

Not applicable.

Additional Graphs, Boyle's Law

Since Boyle's law describes that the pressure of a gas is inversely proportional to its volume [2] (its equation can be $PV = K$), its general graph is:



Sample Calculations, Boyle's Law

Trial 1:

$$PV = K,$$

Average of K values in Trial 1

$$= \frac{(99.45 * 15) + (135.92 * 9.0) + (79.45 * 20) + (115.40 * 17) + (226.23 * 5.0) + (84.71 * 18)}{6}$$

$$= 1486.96 = 1.5 * 10^3$$

Trial 2:

$$PV = K,$$

Average of K values in Trial 2

$$= \frac{(101.74 * 15) + (135.26 * 9.0) + (77.85 * 20) + (117.66 * 17) + (226.24 * 5.0) + (86.25 * 18)}{6}$$

$$= 1497.39 = 1.5 * 10^3$$

(Calculations explained and mentioned in discussion)

Assessment Criteria Sheet

* Send to Cian

~~Wanda~~ Rikki Romana

Criteria	Marks Possible	
1. Plan to vary only one independent variable at a time.	1	
2. Controls on other variables are clearly stated	1	
3. Measurement errors are minimized by appropriate procedures or apparatus.	1	
4. The methods are clear enough to be followed by other students	1	
5. Trials and replicas are stated	1	
6. Limitations of the experimental design are described	1	
TOTAL	6	

Wanda

9-10-2018