

Experiment Title:

Validation of Gas Laws

Author(s) Name(s):

Oumou Diallo

Submitting Author's Partner:

Charles Cayouette

TA (Demonstrator)'s Name:

Weiyi Zhou

Date Experiment Performed:

September 12th, 2019

Date Experiment Submitted:

September 18th 2019

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 outlined in Lab Manual

Procedure – Boyle's Law:

1. Ensure that all needed equipment is ready for use
2. Secure the gas pressure sensor to LabQuest2
3. Calibrate the syringe to the desired initial volume (20mL)
4. Connect the syringe to the valve of the gas pressure sensor
5. Fasten the syringe in place (a half-turn)

6. Input the data into LabQuest2 (*Volume : mL*) (*Pressure : kPa*)
7. Begin data collection
8. Hold the plunger of the syringe at the initial desired volume (20mL)
9. Wait until the pressure reading stabilizes (press ***keep***)
10. Add ***0.8 mL*** to the gas volume in mL on the LabQuest2
11. Move the plunger down to 17mL and press ***keep***
12. Repeat the 10th step
13. Repeat steps 10 and 11 by reducing the plunger's volume by 3mL intervals
14. Continue in this manner until the pressure in the syringe has been measured at 6 different volumes.

Discussion:

Charles' Law

Charles' Law proves that at constant pressure, the volume occupied by a determined amount of gas is proportional to the temperature. This law was further proven to be right throughout the experiment when the Erlenmeyer flask was moved from the boiling water to the ice bath. Once put in the ice bath, the gas rapidly contracted particles in the air. Gaining more kinetic energy, those particles then moved apart more extensively, which is what increased the volume inside the flask and caused the water to enter the container in order to create equilibrium between the two systems.

During the lab, there were many notable sources of error.

Here are a few :

- Once the step in the experiment requiring the ice bath was reached, there was no more ice to be used, which changed the course of the experiment, seeing as simply cold tap water was forced to be used instead.
- Another reason for error is that there could have made a wrong measurement estimation. This could have happened while noting the temperatures of the 'ice' bath, later causing errors in calculations.

To avoid these errors in the future, more cautious measures would have to be taken to ensure that the variables obtained are in fact correct.

Boyle's Law

Boyle's law describes that while the volume decreases of a given ideal gas, the pressure exerted by the gas particles increases due to the kinetic energy between the gas particles. This relation between pressure and volume is mathematically inversely proportional forasmuch as the temperature remains constant in the system. In an inverse proportion, the product of the independent and dependent variables is equal to a constant (K); when one value of the variables (P) increases, the other (V) decreases. (Refer to "***Sample Calculations, Boyle's Law***")

It is important when taking scientific measurements to take multiple readings during the experiment to minimize the chance of random and systematic errors. Random errors are inevitable and are present in any scientific measurements. Systematic errors can be caused by inaccurate calibration of the equipment, for instance, the gas pressure sensor and tampering of the environment while taking measurements affect the outcome of the experiment. It is therefore important to take multiple readings of the dependent variables (P) for the same value of the independent (V) to increase the likelihood of the calculations to be of their true value.

While working with Boyle's law two variables require to be taken into consideration to be met for other gas variables, the independent as pressure (P) of the system in kilopascals (kPa) and temperature (T) measured in degrees Celsius ($^{\circ}\text{C}$). These variables were taken into consideration in the experiment. These variables were inversely proportional, signifying that when the independent variable (Volume) increases the dependent variable (Pressure) decreases. To ensure the variables remained constant simply following the instructions to maintain equilibrium. The less the system has been tampered with the less inaccurate the obtained results were; the less systematic errors lead to better results in calculations, directly affecting the results.

Conclusion:

In conclusion, the purpose of the experiment was to prove or disprove Charles and Boyles' Laws. The point of Charles' Law was to observe the relationship between pressure and volume, while Boyles' Law was to distinguish the interconnection of volume and temperature of ideal and real gases.

Reference(s):

Grant Colwell

Appendix:

Raw Data:

Sept. 12th 2019

Experiment 1: Validation of Gas Laws
VERIFICATION OF CHARLES' LAW

Variables:

- ↳ dependent: temperature
- ↳ independent: volume

Procedure:

As outlined in Lab Manual

GIVENS

INITIAL TEMP. ICE WATER: 21°C

INITIAL TEMP. B. WATER: 103°C

FINAL TEMP. ICE WATER: 21°C 22°C

FINAL VOLUME OF WATER: 35 mL

^{IN FLASK} graduated cylinder ~~(100 mL)~~

Initial volume of water: 0 mL

VOLUME OF BEAKER: 150 mL
ERLENMEYER FLASK

DATA ANALYSIS:

THE VOLUME OF THE GAS (V_2) AT T_2

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

THEREFORE,

$$V_2 = 150 \text{ mL} - 35 \text{ mL}$$

$$= 115 \text{ mL}$$

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USING CHARLES'S LAW ($\frac{V_1}{T_1} = \frac{V_2}{T_2}$) TO VERIFY THE DATA

DATA: 103°C

$$T_1 = 103^\circ\text{C} \quad T_2 = 22^\circ\text{C} \quad V_1 = 150 \text{ mL} \quad V_2 = 35 \text{ mL}$$

ISOLATE FOR V_1 , $V_1 = \frac{V_2}{T_2} \times T_1$

THEREFORE, IN AN IDEAL CASE:

$$V_1 = \frac{35 \text{ mL}}{22^\circ\text{C}} \times 103^\circ\text{C} = 159.1 \text{ mL} \quad 163.86 \text{ mL}$$

103°C

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PERCENT ERROR:

USING THE FORMULA $\% \text{ ERROR} = \frac{V_1/T_1 - V_2/T_2}{V_1/T_1} \times 100\%$

THEREFORE,

$$\% \text{ ERROR} = \left| \frac{150 \text{ mL} / 103^\circ\text{C} - 35 \text{ mL} / 22^\circ\text{C}}{150 \text{ mL} / 103^\circ\text{C}} \right| \times 100\%$$

USING THE ABSOLUTE VALUE AS THE NUMERATOR,

$$\% \text{ ERROR} = \left| \frac{-0.134598411}{1.45631068} \right| \times 100\% = 9.24\%$$

THE PERCENT ERROR CALCULATED IS 9.24%.

Boyle's Law is as follows: $PV = k$

Where k is Boyle's constant.

Using the differences of the peak and initial entries of pressure and the volume of the correlating entry:

$$\Delta P = P_{\text{peak}} - P_{\text{initial}}$$

$$\Delta P = 118.68 - 102.15 \text{ kPa}$$

$$= 16.53 \text{ kPa}$$

$$\Delta V = V_{\text{peak}} - V_{\text{initial}}$$

$$\Delta V = 20 - 17 \text{ mL}$$

$$= 3 \text{ mL}$$

Using these values to calculate Boyle's constant by using the formula $PV = k$:

$$k = 16.53 \text{ kPa} \cdot 3 \text{ mL}$$

$$= 49.59$$

Sept. 12th 2019.

Experiment 2: Validation of Gas Laws VERIFICATION OF BOYLE'S LAW

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Variables:

↳ dependent = pressure

↳ independent = volume

Procedure:

- #1. Ensure that all needed equipment is ready for use.
- #2. Secure the gas pressure sensor to LabQuest2.
- #3. Calibrate the syringe to the desired initial volume (20mL)
- #4. Connect the syringe to the valve of the gas pressure sensor
- #5. Fasten the syringe in place. (a half-turn)
- #6. Input the data into LabQuest2.
↳ pressure, volume, mL, kPa. pressure (kPa), volume (mL)
- #7. Begin data collection
- #8. ~~Constrain the syringe to the initial desired volume~~
- #8 #9. Hold the plunger of the syringe at the initial desired volume (20mL)
- #9 #10. Wait until the pressure reading stabilizes (Keep)
- #10 #11. Add 0.8 to the gas volume in mL on the LabQuest2
- #11 #12. Move the plunger down to 17mL (Keep)
- #12 #13. Add 0.8 to the gas volume in mL
- #13 #20. Repeat steps 18-19 by reducing the plunger's volume by 3mL intervals.
- #14 #21. Continue in this manner until the pressure in the syringe has been measured at 6 different volumes

Givens:

↳ +0.8 kPa + 0.5 mL to each entry.

1st entry: kPa = 102.15 Vol = 20 mL

2nd entry: kPa = 118.68 Vol = 17 mL

3rd entry: kPa = 105.08 Vol = 14 mL

4th entry: kPa = 102.56 Vol = 11 mL

5th entry: kPa = 102.18 Vol = 8 mL

6th entry: kPa = 102.11 Vol = 5 mL

Additional Data, Charles' Law

Initial temperature of the water : 21°C

Final temperature of the water within the flask : 22°C

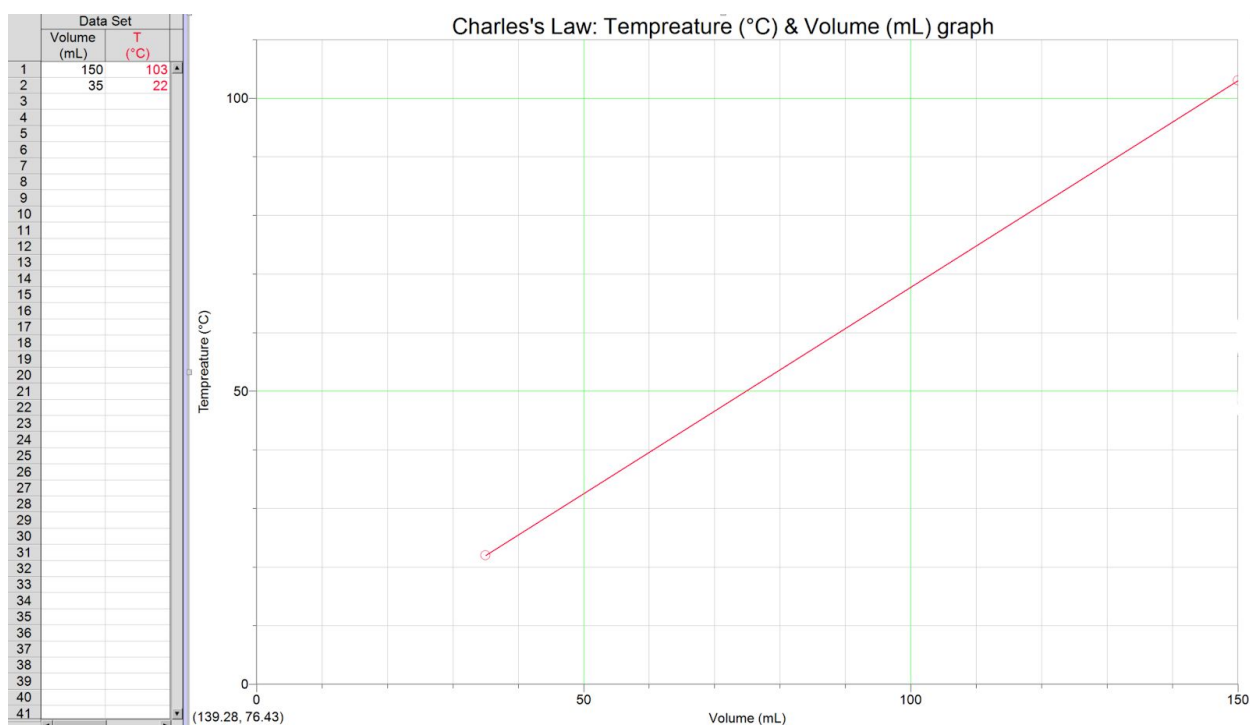
Initial temperature of the boiling water : 103°C

Initial volume of water in the graduated cylinder : 0 mL

Final volume of water in the graduated cylinder : 35 mL

Volume of the Erlenmeyer flask : 150 mL

Additional Graphs, Charles' Law



Sample Calculations, Charles' Law

Data Analysis : the volume of the gas (V_2) at T_2

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

Therefore,

$$\begin{aligned} V_2 &= 150 \text{ mL} - 35 \text{ mL} \\ &= 115 \text{ mL} \end{aligned}$$

Using Charles' Law ($\frac{V_1}{T_1} = \frac{V_2}{T_2}$) to verify the data :

$$V_1 = 150 \text{ mL}$$

$$V_2 = 35 \text{ mL}$$

$$T_1 = 103^\circ\text{C}$$

$$T_2 = 22^\circ\text{C}$$

Isolate for V_1 :

$$V_1 = \left(\frac{V_2}{T_2} \right) \times T_1$$

Therefore, in an ideal case;

$$\begin{aligned} V_1 &= (35 \text{ mL}/22^\circ\text{C}) \times 103^\circ\text{C} \\ &= 163.86 \text{ mL} \end{aligned}$$

Percent Error :

Using the % error formula : $\frac{\frac{V_1}{T_1} - \frac{V_2}{T_2}}{\frac{V_1}{T_1}} \times 100\%$

Therefore,

$$\% \text{ error} = \left| \frac{\frac{150 \text{ mL}}{103^\circ\text{C}} - \frac{35 \text{ mL}}{22^\circ\text{C}}}{\frac{150 \text{ mL}}{103^\circ\text{C}}} \right| \times 100\%$$

Using the absolute value as the numerator,

$$\begin{aligned} \% \text{ error} &= \left| \frac{-0.134598411}{1.45631068} \right| \times 100\% \\ &= 9.24\% \end{aligned}$$

The calculated percent error is 9.24%

Additional Data, Boyle's Law

Givens :

1st entry : Pressure = 102.15 kPa

Volume = 20.08 mL

2nd entry : Pressure = 118.68 kPa

Volume = 17.08 mL

3rd entry : Pressure = 105.08 kPa

Volume = 14.08 mL

4th entry : Pressure = 102.56 kPa

Volume = 11.08 mL

5th entry : Pressure = 102.18 kPa

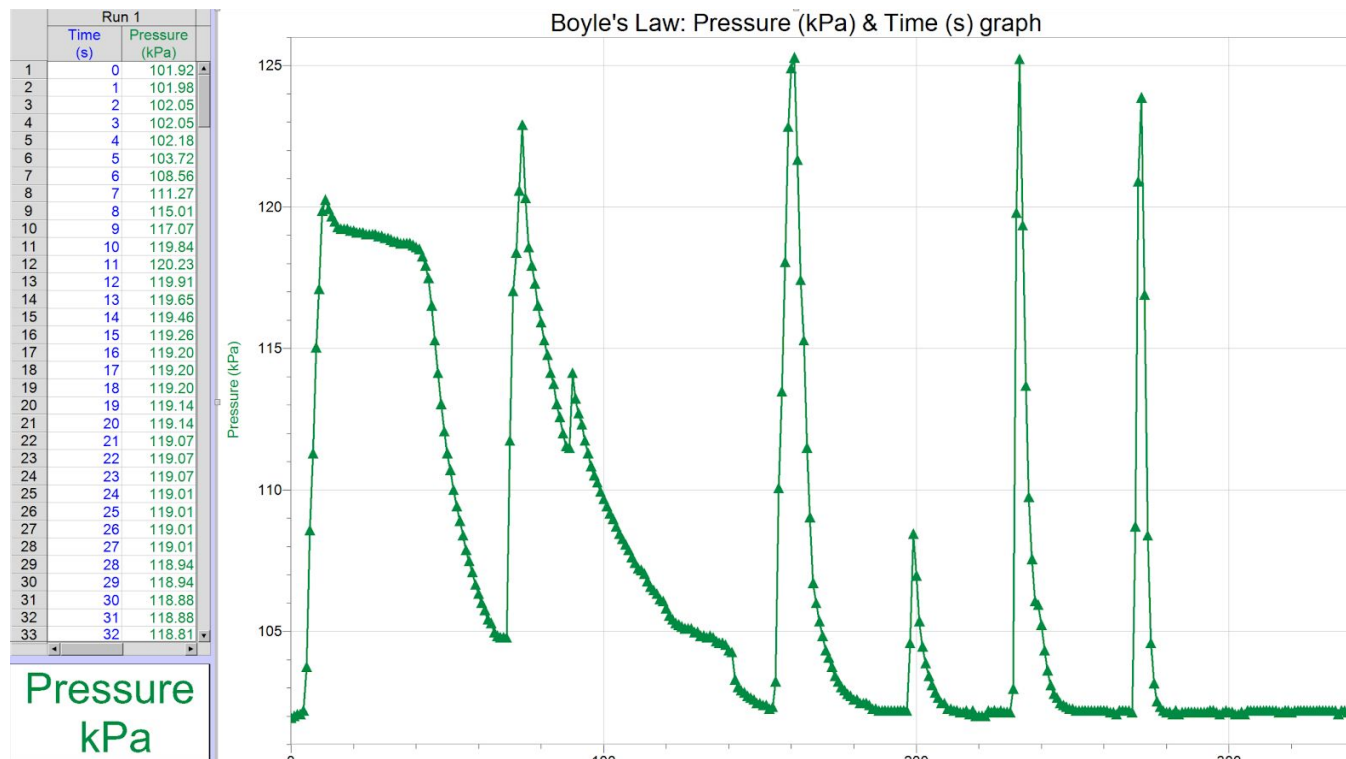
Volume = 8.08 mL

6th entry : Pressure = 102.11 kPa

Volume = 5.08 mL

**To compensate for the 0.8 mL of space inside the pressure sensor itself, 0.8 mL was automatically added to the volume of each entry.*

Additional Graphs, Boyle's Law



Sample Calculations, Boyle's Law

We can then apply the relationship between pressure and volume to calculate a Boyle's law constant with the formula $V = K/P$, where K is Boyle's constant.

Employing the formula $V = K/P$, we can then isolate to find K giving,

$$PV = K$$

Using the differences in the peak and initial data of pressure and volume at the corresponding entry

$$\begin{aligned}\Delta P &= P(\text{Peak}) - P(\text{Initial}) \\ &= 118.68\text{KPa} - 102.15\text{KPa} \\ &= 16.53\text{KPa}\end{aligned}$$

$$\begin{aligned}\Delta V &= V(\text{at Peak}) - V(\text{initial}) \\ &= 20\text{mL} - 17\text{mL} \\ &= 3\text{mL}\end{aligned}$$

To then use these values to calculate Boyle's constant with the formula $\Delta P \Delta V = K$

$$K = 16.53 \text{ kPa} \times 3 \text{ mL} \\ = 49.59$$

Boyle's constant calculated is 49.59

Assessment Criteria Sheet

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. Oumou Diallo
		Date:		Sept. 12 th 2019
		Assessment		
Criteria:	Marks Possible	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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12. Experiment 1

repeat steps 18-19 by reducing volume (20 mL)

repeat steps 18-19 by reducing volume (20 mL)

repeat steps 18-19 by reducing volume (20 mL)

TA NAME:	Wei-yi Zhou	Name of students in group:		a. Oumou Diallo
		Date:		Sept. 12 th 2019
		Assessment		
Criteria:	Marks possible	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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