

Experiment 1. Verification of Boyle's and Charles's Law

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September 20th 2018

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Experiment 1: Proving Charles's and Boyle's Laws

Introduction:

Gases are very unique due to its many properties such as its volume, pressure, mass, and temperature. Gas particles are in constant movement, and as they move, many collisions occur within the small occupied space. This constant movement indicates that they can be compressed and also demonstrates that the particles have gaps in between each particle which creates a weak bond to each other. An ideal gas has properties of both “volume and molecule particles that are extremely small that it has no effect on how the gas behaves”(Olmsted, Williams & Burk, 2016). Ideal gas behavior is all dependent on its environmental conditions, for example, the volume and or temperature. In order to identify the different behaviours, the Ideal gas law stated below is used.

$$pV=nRT \quad [1]$$

Within extreme conditions this law analyzes “the relationship between volume and pressure of a confined gas”(T.S.Eliot,2018). Boyle's law consist of two variables volume and pressure, which together creates a constant. With this given equation it demonstrates that volume and pressure are inversely proportional.

$$pV=K \quad [2]$$

Furthermore ideal gases can also be defined by Charles law. This law relies on the relationship between volume and temperature at a constant pressure. Charles law determines if the volume increases with respect to the increase of temperature, in other words it “identifies the direct proportionality between volume and temperature at constant pressure” (JS, 2018).

$$V_i/T_i=V_f/T_f \quad [3]$$

Procedure - Boyle's Law:

1. Put on all safety equipment, lab coat and goggles
2. Prepare gas pressure sensor and air sample
 - a) Ensure that LabQuest2 is on and connect the gas pressure sensor
 - b) Prepare the syringe plunger to a desired volume which will be used to begin and end the trial
 - c) Connect the syringe to the pressure sensor
3. Prepare LabQuest2 for data collection
 - a) Ensure Mode is set to Events with Entry
 - b) Enter independent and dependent variables. Volume mL, pressure kPa and click save
4. Data collection and Plotting of data

- a) Hold plunger at chosen volume to begin
 - b) Once volume is stabilized, press keep on LabQuest2 located in the bottom left corner of the screen
 - c) Enter the pressure and volume but with an addition of 0.8 mL due to extra volume in the gas pressure sensor, click okay.
 - d) Repeat steps 4. A-C 10 times, change the volume each time. (Note: last trial must finish with volume use to begin the experiment)
 - e) Record data in the table of lab book
5. Save graph created by LabQuest2 on an USB
 6. Clean up all equipment and tidy station

Procedure - Charles's Law:

1. As describe in the lab manual (T.S.Eliot,2018)

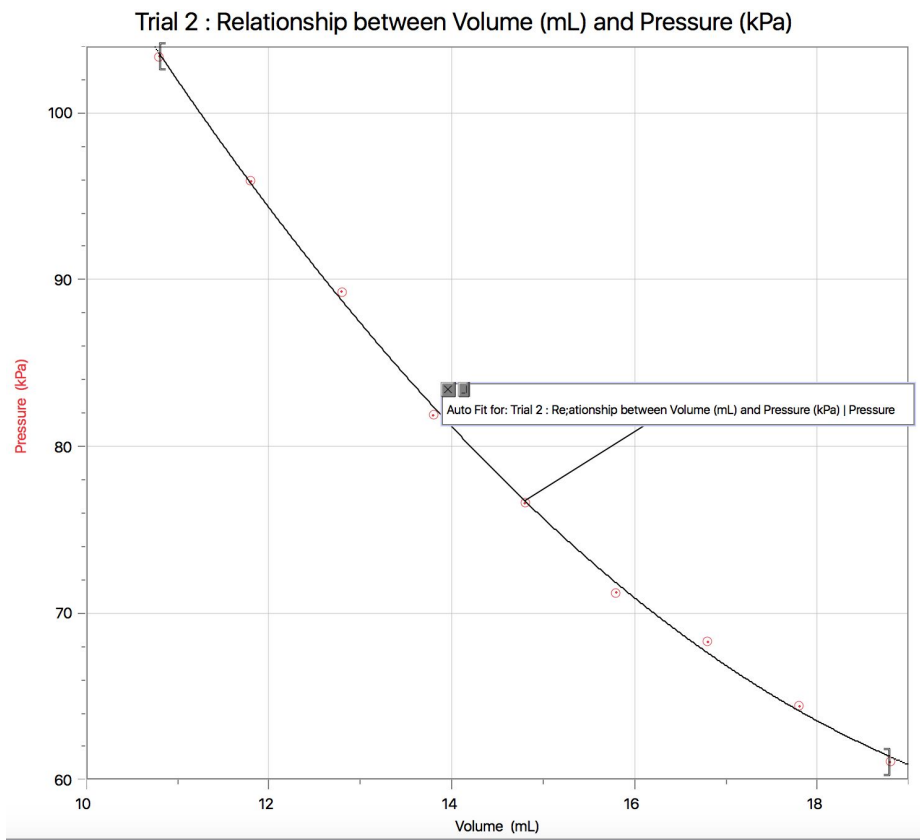
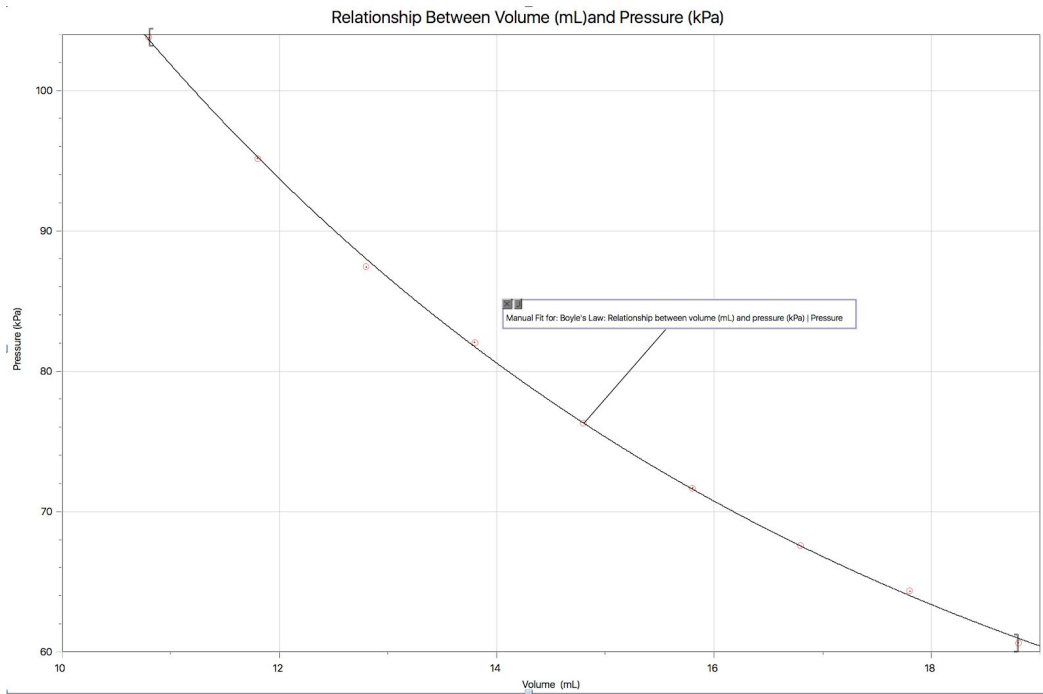
Data and Observation/ Results :

Boyle's Law Trial 1:

Volume (mL) +0.8	Pressure (kPa)
10.8 mL	103.77 kPa
11.8 mL	95.15 kPa
12.8 mL	87.43 kPa
13.8 mL	82.03 kPa
14.8 mL	76.30 kPa
15.8 mL	71.68 kPa
16.8 mL	67.54 kPa
17.8 mL	64.32 kPa
18.8 mL	60.63 kPa
10.8 mL	Not used on graph

Observation :

- Pressure sensor fluctuated between numbers, does not stabilize long enough for proper reading.
- As the volume increases it became challenging to hold syringe in place for reading



Charles Law Trial 1:

Temperature (°C)	Volume (mL)
Boiling point - 100°C	V _{cw} - 33.9 mL
Ice bath before erlenmeyer - 6°C	V ₂ - 155 mL
Ice bath after erlenmeyer - 5°C	V ₁ - 121.1 mL

Charles' Law Trial 2:

Temperature (°C)	Volume (mL)
Boiling point - 100°C	V _{cw} - 36.1 mL
Ice bath before erlenmeyer - 5°C	V ₂ - 155 mL
Ice bath after erlenmeyer - 5°C	V ₁ - 118.9 mL

Calculations:

Boyle's Law:

Boyle's Law constant: $P \cdot V = K$

$$103.77 \text{ kPa} \cdot 10.8 \text{ mL} = 1120.716 \text{ kPa} \cdot \text{mL}$$

Justification: Boyle's Law observes the nature of a gas when the temperature is held constant and also characterizes an inverse relationship between pressure and volume. Therefore, multiplying the pressure and the volume together gives a constant number in these conditions.

Charles' Law: Trial #1 -

Total volume of the erlenmeyer flask (V₁): 155 mL

Volume of the water in the erlenmeyer flask after the ice bath (V_{cw}): 33.9 mL

Volume occupied by the gas (V₂): $V_1 - V_{cw} = 155 \text{ mL} - 33.9 \text{ mL} = 121.1 \text{ mL}$

Average from trial #1 and #2: $(121.1 \text{ mL} + 118.9 \text{ mL})/2 = 120 \text{ mL}$

Percent Error Formula: $[(V_1/T_1) - (V_2/T_2)]/(V_1/T_1) \times 100\%$

$$\% \text{error} = [[(155 \text{ mL} / 6^\circ\text{C}) - (121.1 \text{ mL} / 5^\circ\text{C})] / (155 \text{ mL} / 6^\circ\text{C})] \times 100\% = 6.24\% \text{ error}$$

Discussion:

Boyle's law is defined as the inverse relationship between volume and pressure of a gas while temperature remains constant. As indicated by the graphs and the raw data, this is exactly what was proven during the experiment. In the presence of constant room temperature, the volume was lowered which produced an increase in the pressure of the gas inside the syringe confirming Boyle's theory. Since $P \cdot V$ gives a constant, that means that $P_1 V_1 = K = P_2 V_2$ which leads to $P_1 V_1 = P_2 V_2$.

During the Boyle's law experiment, measurement for the dependent variable was taken twice for the first independent variable. This could be to verify that there was no major fluctuation in pressure at the first volume as the whole experiment was conducted relative to the first measurement. Similar to how multiple trials are done for the same experiment, it could have been done for precision.

Charles' law states that at a given constant pressure, the volume of a gas is directly proportional to the temperature in Kelvin. During the experiment, the gas was heated in a beaker of water to 100°C and then cooled down in a 6°C ice bath. This resulted in a reduction in the volume of the gas significantly. According to Charles' law, in this situation where the atmospheric pressure is constant in the laboratory, the volume of the gas should increase/decrease along with an increase/decrease in temperature and this is exactly what was observed.

Possible sources of error include the syringe being manually held at a certain volume which leads to fluctuation in the exact volume and pressure being measured during the Boyle's law experiment, and letting some of the gas escape from the erlenmeyer flask after heating during the Charles' law experiment. The syringe would go back to 0 if not held properly due to the gas trying to escape. The gas would escape from the erlenmeyer flask during the seconds the heater was turned off and the hole in the stopper was going to be covered by the thumb.

Conclusion:

The experiments that were conducted proved both Boyle's and Charles' theory of ideal gases. As the volume of a gas was increased, the pressure reduced when temperature was held constant. As the temperature of a gas was decreased under constant pressure, the volume of the gas decreased as well. Therefore, the notion of the laws the experiment was started with was confirmed.

Raw Data:

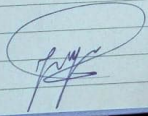
Boyle's Law Sep 13th, 2018

Trial #1

Volume (mL)	Pressure (kPa)
10.8	103.72
11.8	95.15
12.8	87.43
13.8	82.03
14.8	76.30
15.8	71.80
16.8	67.54
17.8	64.32
18.8	60.63
10.8	105.36

Trial #2

Volume (mL)	Pressure (kPa)
10.8	103.38
11.8	95.91
12.8	89.26
13.8	81.87
14.8	76.62
15.8	71.22
16.8	68.28
17.8	64.42
18.8	61.07
10.8	105.71



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Observations

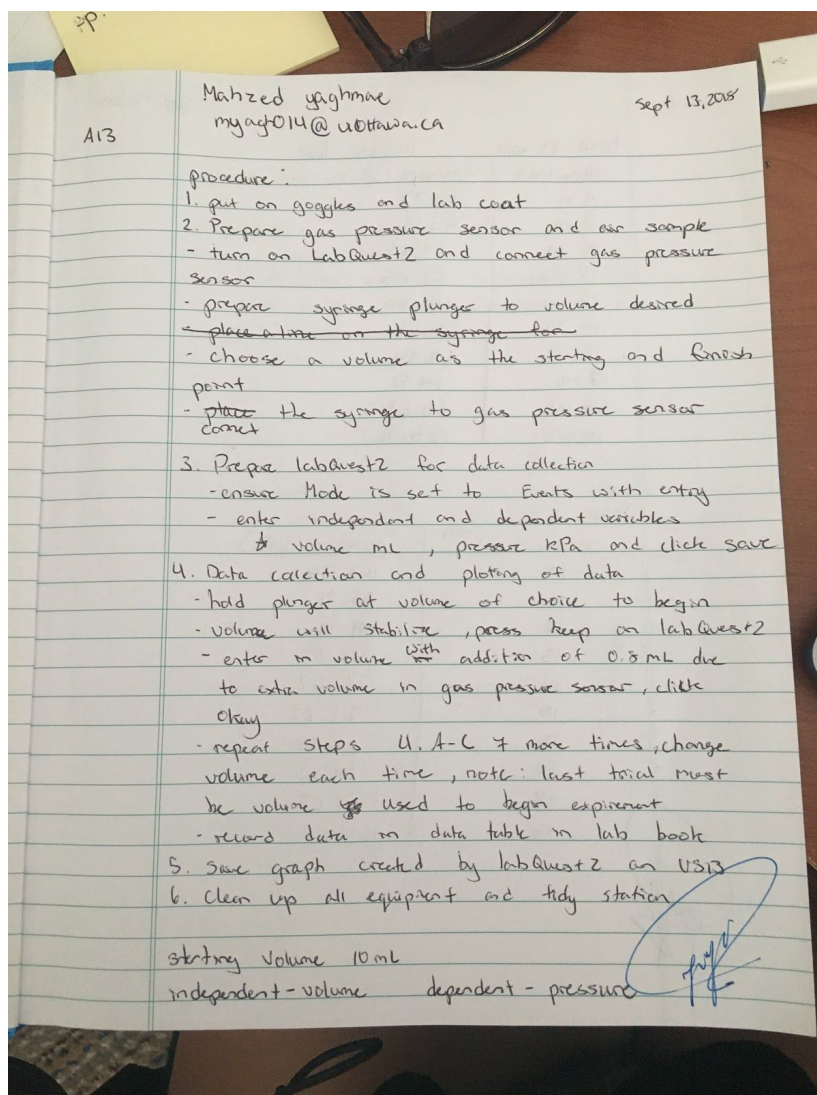
Trial #1

Boiling point: 100°C
ice bath temperature: 6°C
V_{new}: 33.9 mL
ice bath temperature after bath: 5°C
V₁: 155 mL
V₂ = V₁ - V_{new} = 155 - 33.9 = 121.1 mL

Trial #2

Boiling point: 100°C
ice bath temperature before submersion: 5°C
ice bath temperature after bath: 5°C
V_{new} = 36.1 mL
V₁ = 118.9 mL
V₂ = 155 mL





References:

JS, T. (2018). *Chemistry, Ideal Gas Behavior* - PubMed - NCBI. Retrieved from <https://www.ncbi.nlm.nih.gov/pubmed/28722965>

Olmsted, J., Williams, G., & Burk, R. (2016). *Chemistry* (3rd ed., pp. 81-83). Toronto: Wiley.

T.S Eliot. (2018). *Do I Dare Disturb The Universe*. (pg.1-12)