Experiment 1: Verification of Boyle's Law

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Introduction:

According to Silberberg et al. (2016), Boyle's Law states that "at a constant temperature the volume occupied by a fixed amount of gas is inversely proportional to the applied (external) pressure" (p. 155). This law can be expressed using the equation $K = pV$. With this knowledge, the temperature of a gas and the number of moles of a gas are also involved in the relationship. This overall relationship can be identified as the Ideal Gas Law, expressed with the equation $pV=nRT$. According to Tenny et al. (2017), the particles of an ideal gas are assumed to have "negligible volume', are "[identical] in [mass] without any [net] force of attraction or repulsion", follow "Newton's Laws' of Motion", and have "no energy loss" due to "perfect elastic collisions". While gases in nature will never satisfy these assumptions of an ideal gas, these concepts are used to simplify the study of general gas behaviour.

In this investigation, a syringe and gas pressure sensor are used to assess this relationship assuming that the gas being sampled acts as an ideal gas. The syringe is used to collect a sample of air at room temperature, while a connected gas pressure sensor is capable of detecting the air pressure for the given volume confined within the syringe and connecting tube. In collecting various volumes of air, it is possible to verify the inversely proportional relationship between the volume and corresponding applied pressures.

Purpose:

To investigate the relationship between pressure and volume of a confined gas in order to verify Boyle's Law.

Apparatus:

- Safety glasses
- Lab coat
- LabQuest2
- Vernier Gas Pressure Sensor
- 20 mL plastic syringe
- USB key
- Black or blue pen
- Lab notebook

Procedure:

1. Put on lab coat and safety glasses.
2. Prepare lab bench; Make sure workspace is cleared then gather equipment.
3. Prepare the Gas Pressure Sensor and an air sample. First, connect the Gas Pressure Sensor to LabQuest2, then turn in on and create a new file. Adjust the plunger of the syringe to collect an 8 mL sample of air. Next, attach and lock the syringe to the valve of the Gas Pressure Sensor by twisting the syringe 180 degrees clockwise.
4. Set-up the LabQuest2 data-collection mode. Set “Volume” as the variable and “mL” as the units.
5. Hold the plunger at the 8 mL mark. After the pressure reading stabilizes, save the data by by tapping “Keep”. Enter 8 mL with an additional 0.8 mL, to accommodate for the total volume of air confined in the syringe and the Gas Pressure Sensor.
6. Repeat step 5 for air samples of 10.8 mL, 12.8 mL, 14.8 mL, 16.8 mL, 18.8 mL, and 20.8 mL. Collect data for another 8.8 mL sample at the end.

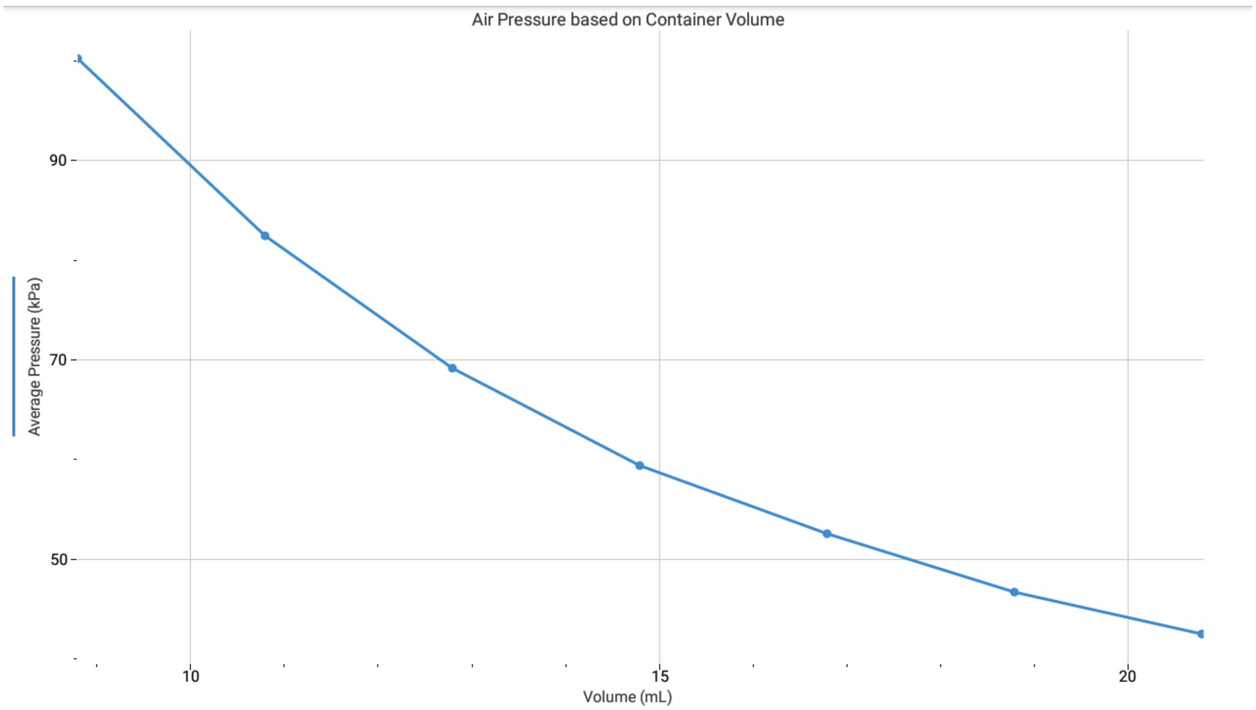
7. Examine the data points for the 8.8 mL samples. Eliminate the data point that least fits the trends observed in this experiment.
8. Analyze the graph and apply a function to represent the data collected.
9. Repeat steps 3 to 8 to complete for two more trials.
10. Insert a USB key into LabQuest 2 to save the experimental data. Record the results in a lab notebook.

Raw and Processed Data:

Table 1. Air Pressure based on Volume of Air Sample

	Pressure (kPa)			
Volume (mL)	**Trial 1**	**Trial 2**	**Trial 3**	**Average**
8.800	100.4	99.39	100.8	100.2
10.80	82.88	82.30	81.94	82.37
12.80	70.01	68.58	68.57	69.05
14.80	59.39	59.08	59.41	59.29
16.80	52.60	52.27	52.35	52.41
18.80	46.61	46.42	46.79	46.61
20.80	42.47	42.29	42.33	42.36

Figure 1. Average Air Pressure based on Container Volume



Calculations:

Assumptions;

- Assume that temperature, *T*, is fixed.
- Assume that the amount of air particles, *n*, is fixed.

Average pressure;

Let *p* represent pressure.

$p_{avg}=(p_1+p_2+p_3)/3$

Let $V = 8.800$ mL, $p_1 = 100.4$ kPa, $p_2 = 99.39$ kPa, and $p_3 = 100.8$ kPa

p_{avg}=(p_1+p_2+p_3)/3

p_{avg}=(100.4 kPa+99.39 kPa+100.8 kPa)/3

p_{avg}=(300.59 kPa)/3

p_{avg}=100.2 kPa

Boyle's law constant;

Let *p* represent pressure, *V* represent volume, and *R* be the constant.

R = pV

Let *V* = 8.80 mL and *p* = 100.2 kPa

R = pV

R = (100.2 kPa)(8.800 mL)

R = 881.8

Data Analysis/Discussion:

A constant can be determined knowing that the pressure and volume of a gas are inversely proportional, assuming that the gas acts as an ideal gas where the temperature and amount of particles are fixed. If it is known that gas pressure is equal to the gas volume's reciprocal value, a constant can be determined by calculating the product of the gas pressure multiplied by the gas volume. When *p* represents the applied air pressure and *V* represents the volume of air, their relationship can be mathematically described by the equation p = 1/V. If the equation were to be rearranged to isolate “1” or the constant, *R*, Boyle’s law could also be described as R = pV. In this experiment, it was determined that an 8.800 mL sample of air with a pressure of 100.2 kPa has a Boyle’s Law constant of 881.8.

It is important to take multiple readings of the dependent variable for the same value of the independent variable in order to assess the precision of the equipment. For each double measurement of the same volume of air, the first and last pressure measurements were never identical. In addition, the air pressure appeared to decrease as more trials were completed. For example, the initial 10.80 mL sample gave a pressure reading of 82.88 kPa. When trials 2 and 3 were complete, the pressure continued to decrease with readings of 82.30 kPa and 81.94 kPa respectively. These changes demonstrates that after manipulation, the syringe and gas pressure sensor may provide different results.

There are many sources of error in this lab that may be due to the method itself while others are experimental errors. The outcome may be due to a change in flexibility of the syringe, air particles escaping the container, or even error in the accuracy of reading the syringe as the plunger may have not been precisely in the same mark as the first measurement. This outcome may also be due to two different people reading the measurements on the syringe. For future experiments, there should be one individual responsible for reading the measurements in order to remain consistent and avoid random error. Another future reference is to make sure the syringe is locked airtight to the gas pressure sensor in order to avoid inaccuracy and loss of air.

Boyle’s Law requires the temperature of the gas and the number of air particles confined to remain constant. In order to maintain the consistency of the gas temperature, all trials were done in the same room and at the same workspace. Throughout the experiment, we assumed that the room temperature of 293.15 K (20℃) was associated with each sample of gas. In order to maintain the consistency of the amount of air particles being confined, the samples were collected in the same pulling manner, rather than pushing. This experiment was designed to collect smaller volume samples and progress to greater volume samples in each trial, so that there would be minimal disruption to the system. Disruption to the system was avoided to prevent changes to the equipment that would result in inconsistent results.

Conclusion:

The results of this experiment verified Boyle's Law. The graph (Figure 1) and our calculations have shown that pressure and volume are indeed inversely proportional just as predicted and our constant was 881.8.