Validation of Gas Laws

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Experiment 1. Validation of Gas Laws

Introduction:

Gases are defined as having a variable volume and shape, meaning they are affected by changes in temperature, pressure and volume. The variables associated with the physical behaviour of gases are pressure (*p*), volume (*V*), temperature (*T*), and amount (mol, *n*); all which are independent of one another. Two important relationships that exist between gases are Charles' Law and Boyle's Law. In order for these laws to work, two variables must remain constant. When two variables remain the same, the gas laws express the effect of one variable on the other. Charles' Law explores the relationship between the temperature and volume of a gas, while Boyle's Law examines the correlation between pressure and volume of gases. Boyle's Law states that "at constant temperature, volume occupied by a fixed amount of gas is inversely proportional to the applied (external) pressure." Charles' Law, closely related, states that "at constant pressure, the volume occupied by a fixed amount of gas is directly proportional to its absolute (Kelvin) temperature". Charles' Law claims that the volume and temperature of a gas are directly correlated together. This is because when gases are cooled they contract and when heated, they expand. "When the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume will be in direct proportion". This can be shown through the formula…

$$V_1 / T_1 = V_2 / T_2$$

To verify Charles' Law the data must show the relationship between temperature and volume of a gas. To do this, a volume of gas is heated then cooled. Then the volume is recorded with each change of temperature. In Boyle's Law, its stated that volume and pressure are inversely proportional. Therefore, when the volume decreases, the pressure increases in proportion and vice versa. The formula is shown as…

$$P_1 V_1 = P_2 V_2$$

To verify Boyle's Law the data must show the indirect correlation between pressure and volume. To do so an initial volume is chosen then the pressure will be recorded, then a new volume is chosen for the gas and the pressure is recorded.

Procedure:

Charles' Law

As described in the lab manual, (*"Do I Dare Disturb The Universe" Verification of Gas Laws*, TS Eliot, Ex.1, p.6,7,8)

Boyle's Law

1. Set up the Gas Pressure Sensor by connecting it to LabQuest 2.

2. Set up the LabQuest 2 data-collection mode, ensuring that units for volume are measured in mL and pressure units are measured in kPa.
3. Attach the syringe to the Gas Pressure Sensor, turning it slowly to lock it in place. Be cautious not to over-tighten the syringe.
4. Move the plunger of the 20mL syringe to the initial volume mark of 10mL.
5. Once the pressure reading stabilizes, tap *Keep* to record the value on your graph. To account for the loss of space in the syringe, add 0.8mL to every volume value measured.
6. Continue to move the plunger to different volumes until you have obtained 6-8 pressure measurements.
7. Take another measurement for pressure at the initial starting value of 10mL to ensure the first reading was accurate.
8. Analyze the data and create a graph which shows the relationship between pressure and volume.

Observations/Data/Results

Table 1. Data and Results in the Determination of Charles' Law

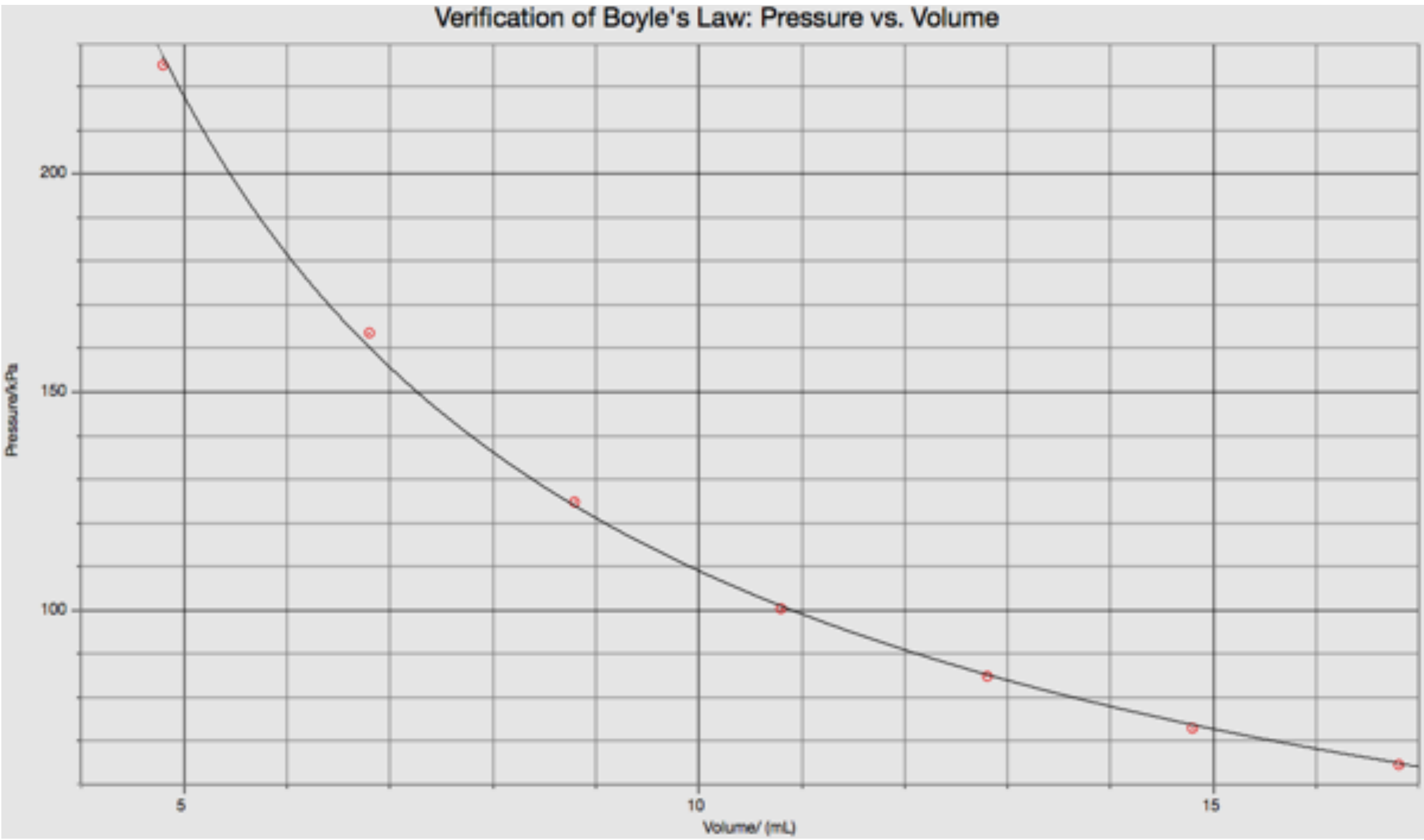
Data	Trial 1
Temp. of Air in Erlenmeyer flask (T_1)	44.1ºC
Temp. of Ice Bath (T_2)	10.8ºC
Volume of Water in Erlenmeyer flask (V_1)	154.5mL
Difference Between Total Volumes (V_2)	125.0mL

Table 2. Data and Results in the Determination of Boyle's Law

Note: When recording the pressures, the Gas Pressure Sensor would not remain completely stable at one specific value, therefore our results are approximations of the actual pressure.

Volume (mL)	Pressure (kPa)
4.8	225.13
6.8	163.46
8.8	124.79

10.8	100.27
12.8	84.86
14.8	72.81
16.8	64.33



Calculations:

A) $V_2 = V_1 - V_{cw}$ = (154.5 - 29.5)mL = 125.0mL
B) (=) = (=) = (1 668.6 = 5 512.5)
C) % error = x 100% = 230.4%
D) Boyle's Law Constant (*k*) = P x V = (225.13 x 4.8) = 1 080.6
E) Average Value for Boyle's Law Constant (*k*)

Table 3. Boyle's Law Constant With Respect to Volume and Pressure

Volume (mL)	Pressure (kPa)	Boyle's Law Constant (*k*)
4.8	225.13	1 080.6
6.8	163.46	1 111.5
8.8	124.79	1 098.2
10.8	100.27	1 082.9
12.8	84.86	1 086.2
14.8	72.81	1 077.6
16.8	64.33	1 080.7

Average Value for (*k*) = Total sum of *k* values / Total number of *k* values = (7 617.7 / 7) = 1 088.2

Discussion:

There are many possible sources of systematic error within our lab, specifically in the Charles' Law portion of the experiment.

In the procedure, the Charles' Law experiment suggests allowing the erlenmeyer flask to boil 6-7 minutes longer once it has reached 100ºC to allow the temperature of the air inside the flask to reach the temperature of the boiling water. We followed this instruction while completing our lab; however, it is evident that a major source of error stemmed from the air inside our flask failing to reach the outside temperature of the water. Another source of error related to the Charles' Law experiment was caused by the temperature of the ice bath. Being an extremely warm day, it was difficult to maintain a desired temperature of 6ºC or cooler. While our original temperature was below that threshold, the ice bath likely became warmer before the transferring of our flask. When moving the erlenmeyer flask to the ice bath, there was the potential for heat loss. Although many preventative measures were taken (such as covering the hole in the stopper), there would still be a slight loss of heat, creating another source of error within our lab. The last major source of error resulted from the submersion of the erlenmeyer flask into our ice bath. If the water levels of the flask and ice bath were not equal then the pressure would equalize and Charles' Law would no longer apply.

Boyle's Law describes the mathematical relationship between volume and pressure, stating that at a constant temperature volume is inversely proportional to the applied external pressure. This can be represented mathematically as $V \propto$. Since this relationship is *always* true, the product of p and V is a constant. As a result, if temperature (T), and the amount (n) remain constant, the equation for Boyle's Law can mathematically be written as $P_1V_1 = P_2V_2$. In our experiment, temperature was never introduced as a variable, meaning it remained at the *constant* room temperature value. If the room temperature varied in any way, this could have introduced a source of error in our lab, as the conditions for Boyle's Law would no longer be true. The amount, (n), remains constant because there is a consistent amount of gas being released from the syringe into the Gas Pressure Sensor. Again, a source of error would have been introduced if the amount of gas released into the pressure sensor fluctuated, and Boyle's Law would no longer apply. To further reduce the risk of error within our experiment, we took two pressure measurements at the starting value of 10.8 mL. This ensures that the first reading for pressure was accurate, and close to the atmospheric value for pressure (101.325kPa).

Overall, our data values for the Boyle's Law experiment appear to be fairly accurate, as our graph shows a correlation of 0.9995 to an inverse function, and our calculated average k value was 1 088.2 (with each individual constant values being close to this number). However, when reading values for pressure on the Gas Pressure Sensor the reading would never completely stabilize, therefore an estimation of the value for pressure was required. If this estimation was incorrect, the reading could have been off by 1-2 kPa, which could have presented a slight source of error within our lab.

Conclusion:

The Charles' Law experiment results had a very large percent error of 230.4%. The volume of air in the Erlenmeyer flask did not correspond to the temperature, which was likely a result of experimental error.

The results for the Boyle's law experiment were far more accurate, as our graph had a strong correlation value (0.9995) compared to a perfect inverse function. As well, all of our values for the Boyle's Law constant, *k,* were approximately the same, with an average value of 1 088.2. The pressure of the gas was what was predicted in correspondence to volume.

References:

1. "Gas Laws." *Transition Metals*, Purdue Chemistry Dept., chemed.chem.purdue.edu/genchem/topicreview/bp/ch4/gaslaws3.html.