Experiment 1: Verification of Gas Laws

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Theories:

Aside from solids and liquids, gases are another example of the states of matter (5). The kinetic molecular theory of gases explains the behaviour of gases. Some postulates of this theory include: there are no forces of attraction between gas particles, they exhibit translational kinetic energy, and individual gas particles have no volume (1). To better reflect this theory, a hypothetical substance called the ideal gas was created. The ideal gas represents the relationship between pressure (P), temperature (T), and volume (V) (4). This is seen in the equation:

$$PV=nRT \quad (4)$$

The purpose of the ideal gas law is so scientists are able to describe and explain the properties of various gases under different conditions. Although, there is no such thing as an ideal gas (4). When gases start to deviate from the standard temperature and pressure, that is when they stray from the idea of an ideal gas. The ideal gas law also encompasses three other gas laws; two of them being Boyle's Law and Charles' Law (1).

Boyle's Law shows the inverse proportional relationship between gas pressure and volume, while the temperature is kept constant. He discovered this by increasing the pressure exerted on a trapped gas that was being measured (2). The independent variable is the volume of a gas and the dependent variable is the pressure of a gas. Some limitations include not being able to measure the pressure with tools, therefore pressure cannot be the independent variable. The mathematical equation for Boyle's Law is:

$$P_1V_1=P_2V_2 \text{ or } PV=k \quad (2)$$

Meanwhile, Charles' Law shows the proportional relationship between the volume and temperature in Kelvin, while the pressure is kept constant (3). The independent variable is the temperature and the dependent variable is the volume of a gas. This law is expressed as:

$$V_1/T_1=V_2/T_2 \quad (7)$$

Procedure:

As described in the lab manual (What in the World ISN'T Chemistry, Dr. Rashmi Venkateswaran, 2018, Exp. 1, p. 7-8) for Charles' Law.

Boyle's Law

1.Prepare the gas pressure sensor by connecting it to LabQuest 2.

2.Take a 20mL syringe and move the tip of the plunger to the 20mL mark.
3.Attach 20mL syringe to the valve of the gas pressure sensor.
4. Record the pressure given on LabQuest 2 into table 2
5.Move the tip of the plunger down in increments of 2 until 8mL is reached and record the pressures into table 2.
6. Move plunger back to the original reading of 20mL and record pressure.
7. Clean up station and remove gas pressure sensor from LabQuest 2.

Tables:

Table 1: Volume and Temperature Data for Charles' Law

	Trial 1	Trial 2
V_{cw} (mL)	38.0	39.5
V_1 (mL)	154.0	153.0
Temperature of Boiling Water (°C)	102.0	102.5
Temperature of Boiling Water (K)	375.5	375.65
Temperature of Ice Bath (°C)	6.0	3.0
Temperature of Ice Bath (K)	279.15	276.15

Table 2: Volume and Pressure Data for Boyle's Law

Volume (mL)	Pressure (kPa)
20.8	102.00
18.8	112.90
16.8	125.91
14.8	142.58
12.8	165.60
10.8	195.40
8.8	225.10

20.8	101.80

Table 3: Tabulations for the Calculations for Charles' Law

	Data	Trial 1	Trial 2
1	Volume/Temperature Pair for V_1 and T_1	V_1=154.0 mL T_1=375.5 K	V_1=153.0mL T_1=375.5 K
2	V_2	116mL	113mL
3	Verifying Charles' Law	0.410mL/K=0.415mL/K	0.407mL/K=0.409mL/K
5	Percent Error	-1.32%	-0.467%

Table 4: Average Values for Charles' Law

Variables	Averages
V_{cw}	38.8mL
V_1	153.5mL
V_2	114mL
Temperature of Boiling Water (°C)	102.3°C
Temperature of Boiling Water (K)	375.6K
Temperature of Ice Bath (°C)	4.5°C
Temperature of Ice Bath (K)	277.65K

Table 5: Calculating Boyle's Law Constants

Pressure (kPa)	Volume (mL)	Constant (PV=k)
102.00	20.8	2120
112.90	18.8	2120
125.91	16.8	2120
142.58	14.8	2110
165.60	12.8	2120

195.40	10.8	2110
225.10	8.8	1980
101.80	20.8	2120

Observations:

During both trials for Charles' Law, when water was boiling on the hot plate, bubbles were formed. This indicated that the Erlenmeyer should remain in the boiling water for another 6-7 minutes. During the experiment for Boyle's law, the syringe was hard to push after a certain measurement. This is important because the initial measurements for this experiment could not be used.

Calculations:

Charles' Law Calculations

1. *Refer to table 3 for the results of the other calculations for questions 1-5*

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

$= 154.0mL - 38.0mL$

$= 116mL$

3. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{154.0mL}{375.5K} = \frac{116mL}{279.15}$

0.410mL/K=0.415mL/K

4. V_{cw} average= $\frac{38.0 + 39.5}{2}$

=38.8

5. % Error = $\dfrac{\dfrac{V_1}{T_1} - \dfrac{V_2}{T_2}}{\dfrac{V_1}{T_1}} \times 100\%$

$= \dfrac{\dfrac{154mL}{375.5K} - \dfrac{116mL}{279.15}}{\dfrac{154mL}{375.5K}} \times 100\%$

$= \dfrac{0.410 - 0.415}{0.410} \times 100\%$

$= -1.32\%$

Boyle's Law Calculations

1. PV=k
(102.00kPa)(20.8mL)
=2121.6 kPa/mL
=2120 kPa/mL

2. PV=2120

Refer to table 5 for the results of the other calculations

Discussion:

The performed experiments for Boyle's Law and Charles' Law was a success in showing the expected relationships between the variables volume and pressure for Boyle's Law and volume and temperature for Charles' Law. Tables 1 and 2 show the quantitative observations noted during the lab. These results, along with the calculations demonstrate the proportional relationship for both laws that were discussed in the theory section. Boyle's Law is an inverse relationship, meaning that when pressure increases, the volume decreases and vice versa. In reference to the data in table 2, Boyle's Law is validated. For example, the volume of the syringe was set at 12.8mL, the pressure being exerted by the gas was 165.60 kPa; while in another instance the volume of the syringe was set at 18.8mL, the pressure being exerted by the gas was

112.90 kPa. These results were expected because in the first measurement when the volume decreased, the pressure increased; meanwhile, in the second measurement, when the volume increased, the pressure decreased. This occurs due to the kinetic molecular theory where it states that trapping gas in a smaller space increases the collisions, meaning that the pressure exerted on the container increases as well (1).

As seen in the theory section, the ideal gas law equation is PV=nRT. This equation encompasses the three other gas laws, which includes Boyle's Law (4). Certain conditions need to be met for these variables present in the ideal gas law, the variables are the number of moles (n) and temperature (T). The variable "R" is the gas constant (4). The variable temperature was taken into consideration during the experiment. To ensure temperature remains constant, the air sample that was taken in the syringe was at room temperature and it did not fluctuate during the Boyle's Law experiment. If the temperature did change, this would have affected our results because Boyle's Law only deals with the changes in pressure and volume. If the temperature changed as well as these two variables, then it would be the combined gas law (6).

Charles' Law was also validated during the experiment. Charles' Law deals with the proportional relationship between volume and temperature. The results obtained from table 1 were expected because when the equation $V_1/T_1=V_2/T_2$ was used, the value on the left equalled the value on the right. For example, in trial 1 0.410mL/K=0.415mL/K and trial 2 0.407mL/K=0.409mL/K. Even though both values did not exactly equal each other due to lab errors, the results still verify Charles' Law. Although, trial 2 gave more precise results because both values were closer to each other compared to those in trial 1.

The importance of taking multiple readings of the dependent variable for the same value of the independent variable is to verify the results from the first reading. In this instance, choosing between the two pressures collected from the experiment does not matter because the values are too close to another and they are similar. In table 5, it shows that the when both the constants are calculated for 20mL, they give the same constant. The small difference between the pressures can be seen in the graph.

As seen in table 5, the constant for the volume at 8.8mL is significantly different from the rest. This is due to the syringe that was very difficult to push at the 8mL mark because LabQuest di. This affected the pressure that was taken which made this value higher than it was. Consequently, the constant for the volume at 8.8mL was skewed because the pressure, 225.10kPa, is *P* in the equation PV=k. In addition, this changed the initial measurements for the volume. In the raw data, the measurements were supposed to go down in increments of 3, instead of 2. But when the syringe was lined up at the 8mL mark, it wouldn't work. Therefore, it was changed to increments of 2 so a sufficient amount of data could be collected.

Conclusion:

This lab was performed to validate Charles' Law and Boyle's Law. It was expected that the variables in each of these laws were proportionally related to one another. After the experiment, it was found that this was correct. The values obtained from the Charles' Law experiment was 0.410mL/K=0.415mL/K for trial 1 and 0.407mL/K=0.409mL/K for trial 2. The value obtained from the Boyle's Law experiment was PV=2120.

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