"DO I DARE DISTURB THE UNIVERSE?"

(T.S.Eliot)

VERIFICATION OF GAS LAWS

T.A: Alexander Daniels

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Introduction:

A gas is a state of matter without definite shape or volume. Particles that make up these gases can range from simple atoms to complex molecules. They have unique behaviours when affected by changes in temperature, volume or pressure.[1] The relationship between temperature and volume is called Charles' law. The movement of a volume of gas with respect to pressure is defined by Boyle's law. The two laws are elaborated on below:

Charles' law describes the relationship between temperature and volume of a gas. French Scientists J.A.C Charles and J.L Gay-Lussac discovered that all gases expand or contract by the same amount for a given temperature change.[2] This discovery shows that at a fixed pressure, the volume of a gas increases linearly with an increase in temperature.[3] Therefore, the two variables are directly proportional. Charles' Law states that:

Figure 1. Charles's Law

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

Boyle's Law states that if an amount of gas is trapped in a container and the volume of the container changes, then the pressure exerted on/by the gas will change inversely proportional to the change of the volume. This law is true for all gases, as long as the temperature of the gas remains constant, and the amount. This law demonstrates the inverse relationship between pressure and volume.[2] Boyle's Law states that:

Figure 2. Boyle's Law

$$P_1 V_1 = P_2 V_2$$

Procedure:

Charles's Law: As described in the lab manual[4]

Boyle's Law:

1. To verify Boyle's Law using a gas pressure sensor, firstly, set up LabQuest 2. Do so by plugging the pressure sensor into the Lab Quest computer, and turning the device on. Choose "New" on the file menu.

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1 Helmenstine, Anne Marie. "Your Chemistry Study Guide for Gases." *ThoughtCo*, ThoughtCo, 8 Mar. 2017, www.thoughtco.com/gases-study-guide-607536.

2 Silberberg, Lavieri, Venkateswaran: Chemistry: The molecular matter of change, chapter 4 Mcgraw-Hill Ryerson Limited. Page 152

3 "Do I Dare Disturb The Universe? Verification of Gas Laws", T.S. Eliot, Experiment 1, Page 2,3

4 "Do I Dare Disturb The Universe? Verification of Gas Laws", T.S. Eliot, Experiment 1, Page 7,8

2. Identify the variables that will be tested, and where they will be used in the Boyle's Law equation. Decide which Variable (pressure or volume) will be your independent and which will be your dependent.
3. Insert the syringe into the sensor by twisting it until you hear a click. Move the plunger on the syringe to the 20ml mark. Remember, to add 0.8mL to each of your volume readings as there is 0.8ml of extra volume inside the pressure sensor itself. (ex. initial volume is 20.8ml).
4. On Labquest begin data collection, begin at 20mL on the syringe. Allow pressure reading to stabilize, tap keep on Labquest and enter 20.8mL. Select ok to proceed.
5. Repeat step 4) for volumes of 18mL, 16mL, 14mL, 12mL, and 10mL (Remember to add 0.8mL on LabQuest). Repeat step 4 for 20mL once again to obtain two 20mL readings. As the pressure increases, there will be more resistance pushing back on the plunger, ensure the plunger is held steady at the desired volume while waiting for the pressure reading to stabilize.
6. On Labquest, examine the plotted points, out of the two 20.8mL values, choose to remove the point that deviates farthest from the curve of the rest of the points.
7. On LabQuest2, choose 'CurveFit > Volume', from the analyze menu. Open the menu below 'Fit Equation' and choose a function to perform on the data. Select 'OK' to return to the graph screen. The function will be plotted.

Data and Observations/Results:

<u>Charles' Law experiment:</u>

Qualitative Observations:

-While the erlenmeyer flask was placed in the beaker of boiling water, steam was observed exiting the beaker.

-When the flask was removed from boiling water, and entered upside down into ice bath, there was suction created through the hole in the rubber topper and water displaced the gas.

Quantitative:

Table 1. Raw Data from Charles' Law Verification:

	Trial 1	Trial 2
Initial Temperature (°C)	100.00	100.00
Initial Temperature (K)	373.15	373.15
Initial Volume (mL)	153.50	153.00
Final Temperature (°C)	4.50	3.50
Final Temperature (K)	277.65	276.65
Final Volume of water in Flask (mLl) (V_{cw})	33.50	56.00

Calculations:

Trial 2:

1) Calculating temperature in kelvin: $T_k = T_c + 273.15$
   ∴ T_k= (100°C) + 273.15K
   ∴ T_k= 373.15 K
   V_1= 153.50 mL ,T_1= 373.15K

2) Calculating $V_2 = V_1 - V_{cw}$= (153.00ml)-(56.00ml) = 97.00mL

3) V_1= 153.00 ml T_1= 373.15K
   V_2= 97.00ml T_2= 276.65K

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \frac{(153.00ml)}{(373.15K)} = \frac{(97.00ml)}{(276.65K)} \qquad (0.41) = (0.35) \quad \text{Ratio} = 0.85$$

4) Percent Error:

$$\frac{\frac{V_1}{T_1} - \frac{V_2}{T_2}}{\frac{V_1}{T_1}} \times 100\% = (0.41-0.35)/\ (0.41) \times 100\% = 14.63\%$$

∴ There is 14.63% error.

<u>Boyle's Law experiment:</u>

Qualitative Observations:

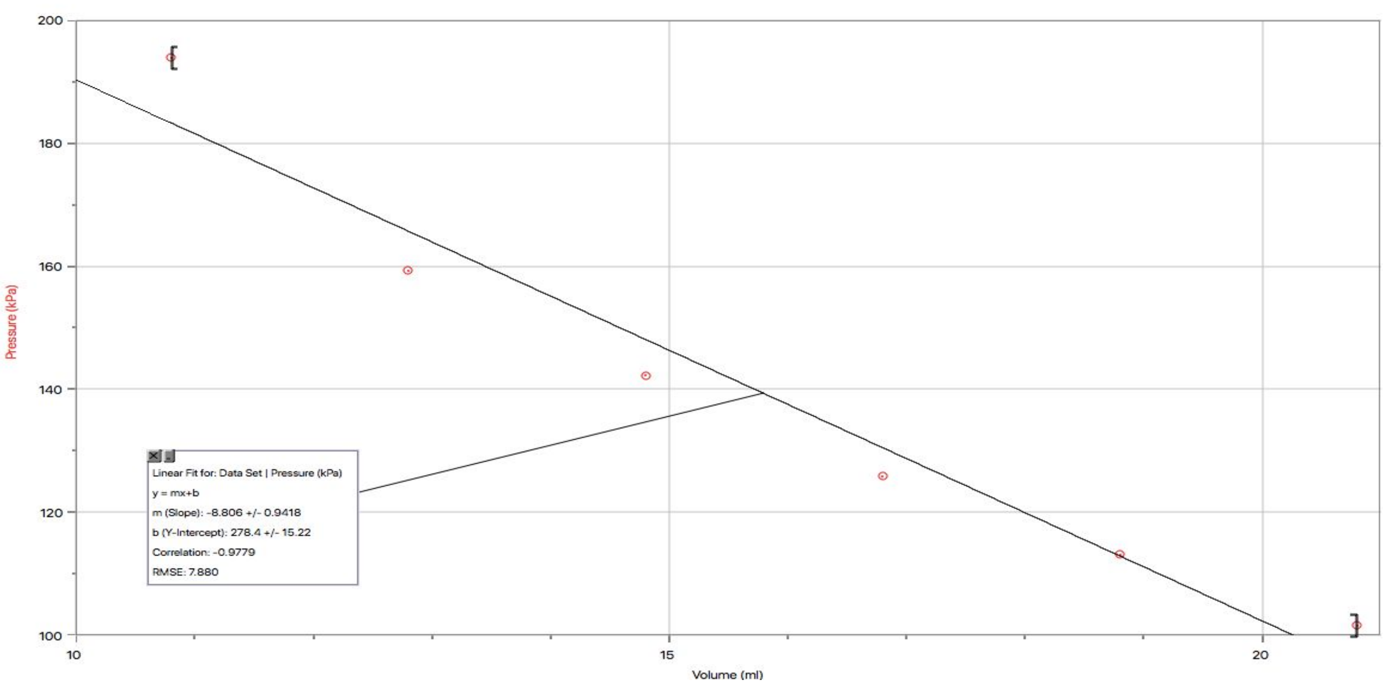
As the volume decreased and the pressure increased, there was a substantial amount of resistance pushing back on the plunger as the volume lowered below 14mL.

Quantitative:

Table 2. Boyle's Law Verification Results:

Volume (ml)	Pressure (kPa)
20.80	101.55
18.80	113.11
16.80	125.84
14.80	142.25
12.80	159.25
10.80	193.87
20.80	102.47

Graph 1. Pressure Vs. Volume:



Calculations/Questions:

1. $P_1 V_1 = P_2 V_2 = k$

$P_1 V_1 = k$

$(101.55kPa)(20.8ml) = 2112.24 = 2.11 \times 10^3$

$P_2 V_2 = k$

$(113.11kPa)(18.8ml) = 2126.4 = 2.13 \times 10^3$

$2.13 \times 10^3 - 2.11 \times 10^3 = 20$

Therefore, there is a difference of 20 between the two k values, which represents error.

Average = $(2.11 \times 10^3 + 2.13 \times 10^3) / 2 = 2.12 \times 10^3$

Therefore, in these conditions, the Boyle's law constant (k) is about 2.12×10^3.

2. The mathematical relationship illustrated by Boyle's law is that pressure and volume are inversely related. As one value increases, the other will decrease and vice-versa. This is true if the amount of gas, and temperature remain the same, as those are external factors, uncontrolled in the Boyle's Law equation. Since both $P_1 V_1$ and $P_2 V_2$ equal the constant, k. One can express Boyle's law in terms of:
$PV = k$

According to the calculations above, $PV = 2.12 \times 10^3$.

3. The independent variable, in this case volume, is one that is controlled, and is changed to determine values of the dependant variable, pressure. The dependant variable is the one being measured, or tested for. The importance of taking multiple readings of the dependant variable at the same independent variable is because it demonstrates possible error that is associated with experimentation. In most situations, more trials, or readings are preferred as one is given more information to work with. With the information one is able to determine which readings deviate from the theoretical information,and what factors would have causes such inaccuracy.

4. The variables that are required to remain constant when using Boyle's Law are temperature of the gas and amount of gas . These variables were taken into consideration during the experiment, as all measurements were taken in the same environment. The

plunger in the syringe was not removed while taking the readings, therefore the amount of gas remained constant. To ensure that these remained constant we tried to limit the amount of time it took to change the volumes and take the readings, in order to minimize any possible time for temperature change. We also did not remove the plunger from the syringe. This does affect our results, as we assumed that both of these variables remained constant, and therefore did not include them in our calculations. If, however, they did not remain constant throughout the experiment, it could explain any error in the data.

Discussion:

Ideally, while verifying Charles' Law, the relationship between temperature and volume is directly proportional, under the conditions that the amount of gas, and pressure remains constant. The result produced from this experiment expressed an error value of 14.63%. Therefore, Charles' law was not verified. This error may have been due to inaccurate readings of measurement tools, which would have led to data between temperature and volume that did not actually correspond. When transporting the flask from the beaker to the ice bath, gas may have escaped due to human error which would lower the volume of water that displaces the gas in the flask. This is a type of random error, which would have been exaggerated by only doing 2 trials of this particular experiment. To reduce or eliminate random error, more trials, ideally five could have been done.

While verifying Boyle's Law, it was shown that the relationship between pressure and temperature of a gas are inversely proportional. During this experiment there was also random error produced. Mainly, as the syringe used was susceptible to large amounts of error at high pressure, due to resistance causing the syringe to slide back. This meant that when performing the experiment one had to hold the plunger in place as the force of pressure pushed back on it, meaning it was hard to get a stable volume point. Error caused by this could have been reduced by doing more trials or using an electronic pressure tester such as the VDAS TD1000, where human error from the resistance at higher pressure would not be a factor. Getting inpercise pressure readings at each volume would ultimately affect the value of k, resulting in different Boyle's constants.

Conclusion:

The variables collected to satisfy Charles' law (V/t=k) are: V_1= 153.00 ml, T_1= 373.15K, V_2= 97.00ml, T_2= 276.65K. This resulted in a percent error of 14.63%. Due to the percent error greater than zero, the results do not fully support Charles' law.

All the data obtained to verify Boyle's law (PV = k), are present in "Table 2. Boyle's Law Verification Results" under "Data and Observation Results." The values used to satisfy PV=k are P_1= 101.55kPa, V_1 = 20.8mL, P_2 = 113.11kPa, and V_2 = 18.8mL. This resulted in two 'k' values of 2.11×10^3 and 2.13×10^3. Receiving 2 different values with a difference of 20 between them for k shows that there was error produced in the experiment, and does not fully support Boyle's law.

Sources Used:

1) Helmenstine, Anne Marie. "Your Chemistry Study Guide for Gases." *ThoughtCo*, ThoughtCo, 8 Mar. 2017, www.thoughtco.com/gases-study-guide-607536.

2) "Do I Dare Disturb The Universe? Verification of Gas Laws", T.S. Eliot, Experiment 1, Page 2-8

3) Silberberg, Lavieri, Venkateswaran: Chemistry: The molecular matter of change, chapter 4 Mcgraw-Hill Ryerson Limited. Page 152