VERIFICATION OF GAS LAWS

Written by:

[redacted]

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General Chemistry Laboratory Report 1

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INTRODUCTION

In this laboratory session, experiments were conducted in order to validate two of the most known gas laws in the field of sciences and those are Charles's Law and Boyle's Law. First of all, before each empirical law is explained, it is worth mentioning what the gas laws actually are.

“Gas Laws are the product of countless experiments on the physical properties of gases that were carried out over several centuries.” [1]

All gases reasonably fall into the category of "ideal gases" because of the many similar properties they share.

The Ideal Gas Law (1) can be described in the form of a formula that can be applied to all gases:

$$P \times V = n \times R \times T \qquad \textit{(Formula 1)}$$

where P is pressure, V is volume, n is the number of moles of a substance, R is a constant and T is the temprature.

Brief description of Charles’s Law:

“For a fixed mass of gas at constant pressure, the volume is directly proportional to the kelvin temperature. It is mathematically expressed as

$$V = constant * T$$ ” [3]

Where V is volume, T is temperature and their division is equal to a proportionality constant.

Brief description of Boyle’s Law:

“For a fixed mass of gas at constant temperature, the volume is inversely proportional to the pressure. It is mathematically expressed as

$$P * V = constant$$ ” [2]

Where P is pressure, V is volume and their multiplication is equal to a proportionality constant. When V increases, P decreases; when V decreases, P increases.

PROCEDURE

First and foremost, before starting the experiment I wore my safety glasses, lab coat and did all the necessary actions to prepare for my work in the laboratory (tying my hair, remove jewellery, I was informed on what to do in case of an emergency, etc.)

The equipment and chemicals I used for Charles's law were the following: 125mL Erlenmeyer flask, 600mL beaker, stopper with hole, digital thermometer, ice bath and an extension clamp.

In order to validate the empirical gas laws during the laboratory session, a few steps had to be taken.

In Charles's law all of our instructions are exactly as described in the lab manual on Brightspace, "Experiment 1 Theory and Instructions" on pages 7 and 8. Our goal for this experiment was to prove that when a volume(V) of a substance changes, so does it's temperature (T in K). In addition, I ran the experiment once and found some interesting conclusions.

The equipment I used for Boyle's law were the following: LabQuest 2, Vernier gas pressure sensor and 20 mL gas syringe.

For Boyle's Law, our main goal was to prove that when a volume (V) of a substance changed so did its pressure (P). This means that we will be using two variables for this experiment; pressure and temperature. The units we will be using are "mL" for the volume and "kPa" for the pressure. Additionally, the volume is considered an independent variable while the pressure is considered a dependent variable.

For Boyle's Law, I was able to conduct the experiment with the help of a Gas Pressure Sensor and a plastic syringe (20mL).

Firstly, I turned on LabQuest2, plugged the Gas Pressure Sensor and connected it to the syringe.

After that, I picked a standard volume of 10mL to begin and end the runs with. It is worth mentioning that because of the space inside the pressure sensor itself, the actual volume should be 10.8mL.

During my first run some volumes were picked for data collection.

The way we do it is by pushing the plunger of the syringe to the volumes we choose in order to indicate the variable pressure (P) on the Labquest2 screen just as described in the lab manual "Experiment 1 Theory and Instructions", pages 8-10. Specifically, by 6 different volume measurements we concluded with a table of the variables.

DATA AND OBSERVATIONS

Observations for Charles's Law

The experiment for Charles's law was ran only once. In the process of it, I gathered several different variables for both the volume (V) and the temperature (T).

Based on the "Experiment 1 Theory and Instructions" from Brightspace (pages 7 and 8) I collected the following data.

Action	During step:	Result
Temperature (T_1) of boiling water	Step 8, page 7	378.15K
Temperature (T_2) of ice bath	Step 11, page 7	286.15K
Volume ($V_{c.w}$) of cylinder water after ice bath	Step 14, page 8	23mL
$V_2=V_1-V_{c.w}$	Step 14, page 8	122mL
Volume (V_1) of water in flask up to stopper	Step 15, page 8	145mL

TABLE 1: This table explains the steps I took in order to conclude to the final results.

It is important to notice that the temperature in °C had to be converted into Kelvin. In addition, in order to verify Charles's law, a few calculations had to be made based on the formula $V_1*T_2=V_2*T_1$

The calculations will be presented in the next part of the report.

The reason why our final estimates (41491 and 46134) are not exactly the same is because we are handling with an experiment within the conditions of a laboratory and not with ideal substances and an ideal environment. So, because of external causes the numbers are approximately close in value to one another. For this reason, I was verified that the experiment is correct and can also be proven by simple calculations.

CALCULATIONS FOR CHARLES'S LAW

Main formulas
$V_1*T_2=V_2*T_1$
T(K)=T(°C)+273.15

- T_1= 273.15 + 105°C=378.15K
- T_2=273.15 + 13= 286.15K
- 145mL*286.15K=41491
- 122mL*378.15=46134
- Percent Error

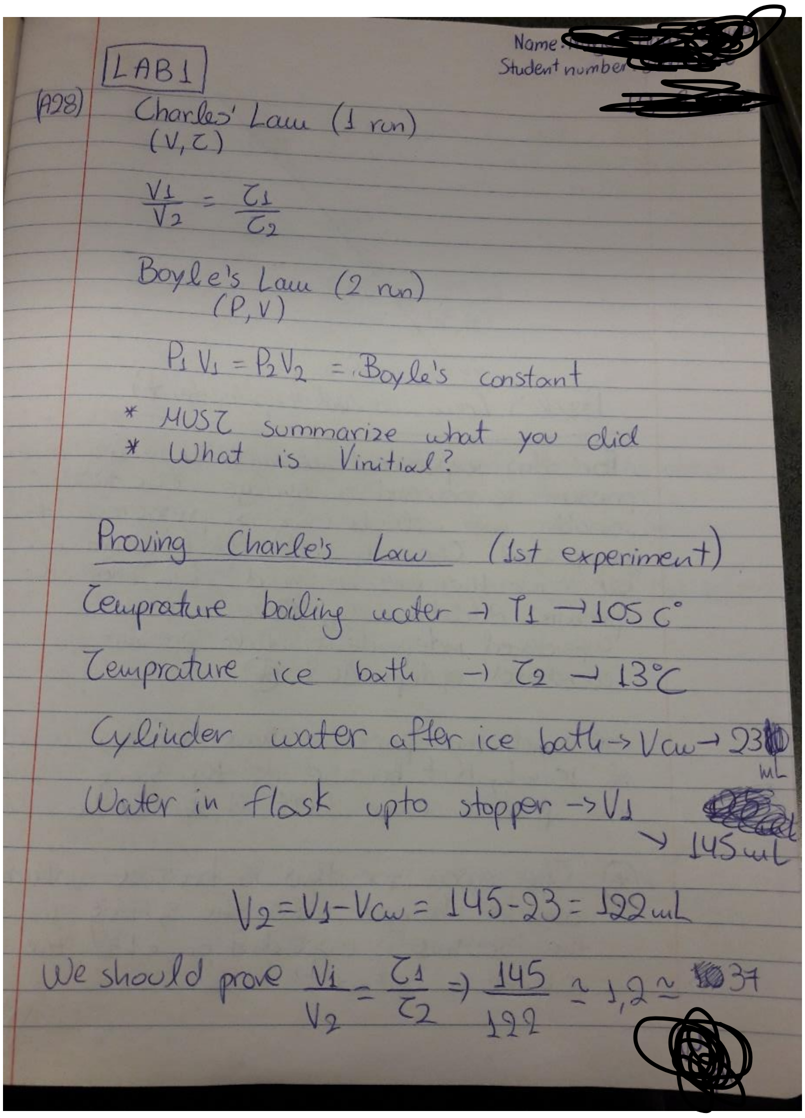
$$\%Error=([(V_1/T_1)-(V_2/T_2)]/[V_1/T_1])*100\%$$

$$=([(145mL/378.15K)-(122mL/286.15K)]/[145mL/378.15])*100\%$$

$$=-0.11188$$

NOTE: The percent error is a number, it has a true value and it indicates an experimental amount that theoretically fell short. In addition, the minus shows that we have not used the Absolute Value Signs.

RAW DATA FOR CHARLES'S LAW


Name: [redacted]
Student number [redacted]

LAB1

(A28) Charles' Law (1 run)
(V, T)

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

Boyle's Law (2 run)
(P, V)

$P_1V_1 = P_2V_2$ = Boyle's constant

* MUST summarize what you did
* What is Vinitial?

Proving Charle's Law (1st experiment)

Temprature boiling water → T_1 → 105 C°

Temprature ice bath → T_2 → 13°C

Cylinder water after ice bath → V_{cw} → 23 mL

Water in flask upto stopper → V_1 → 145 mL

$V_2 = V_1 - V_{cw} = 145 - 23 = 122$ mL

We should prove $\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow \frac{145}{122} \simeq 1,2 \simeq$ 37

[redacted]

It is worth mentioning that, I copied the formulas that were written on the board during the laboratory. I noticed that the formula for Charles's law was written incorrectly (right after the laboratory session), so the wrong written formula is not my mistake.

In addition, during the experiment I measured the temperature of the boiling water in the beaker (after we had placed the flask in it) and observed the temperature: 105 °C which obviously is not acceptable. The reason for this odd temperature is most likely the cause of using a defective thermometer.

Observations for Boyle's Law

With careful observation, for the first run, I ended up forming the following table (*TABLE 2*) which shows how the change of volume of a gas can affect the pressure of itself.

It is worth mentioning that, my standard point of volume is 10 mL but because of the space inside the pressure sensor itself the actual volume should be 10.8mL. Moreover, I began and ended the experiment with the volume 10.8mL which correlates to a pressure of about 100 kPa.

The volume is considered an independent variable while the pressure is considered a dependent variable because volume can be changed using, for example, a syringe, while the pressure is dependant on what the volume is set at.

By noticing this table, one can see that as the volume increases, the pressure decreases and vice versa. This phenomenon can be justified by the fact that pressure is inversely proportional to the volume ($P_1*V_1=P_2*V_2$).

Finally, when the volume of the gas is 10.8mL, the first and last estimates of pressure are not exactly 100kPa. The reason for this is that we are dealing with substances in the laboratory instead of solving chemistry problems from a textbook because in the first case real gases are examined, whereas in the second case, ideal gases are imagined. In general, real gases are substances that can be affected by external factors (E.g. Humidity, atmospheric temperature, etc.)

V (mL)	P (kPa)
10.8	99.92
5.8	185.92
15.8	68.42
3.8	225.58
8.8	124.77
10.8	100.49

TABLE 2: Data collection of the experiment's first run, where volume is V counted in mL and pressure is P counted in kPa.

Once again, with careful observation for the second run, I ended up forming the following table (*TABLE 3*) which shows how the change of volume of a gas can affect the pressure of itself.

By noticing this table, one can see that as the volume increases, the pressure decreases and vice versa. This phenomenon can be justified by the fact that pressure is inversely proportional to the volume ($P_1*V_1=P_2*V_2$).

My standard point of volume is 10.8 mL once again because I wanted not only to observe the difference in pressure between the first and last try but also compare the pressure estimates from the first table too. Just like the previous table, it is worth noticing that when the volume is 10.8 mL the pressure reaches close to 100kPa and the reason why we do not have exact numbers is because we are dealing with real gases and not ideal ones. In conclusion, all of our 10.8mL in volume indicate an amount of approximately 100kPa.

V(mL)	P(kPa)
10.8	100.17
6.8	161.22
11.8	91.15
12.8	83.71
16.8	63.60
10.8	98.92

TABLE 3: Data collection of the experiment's second run, where volume is V counted in mL and pressure is P counted in kPa.

A final observation I made by conducting 2 runs of the experiment was, the more I pushed the plunger of the syringe, the higher the pressure became which made it tricky for me to keep the plunger close to the smaller numbers of volume in order to record the pressure indicated to that volume.

CALCULATIONS FOR BOYLE'S LAW

Main formula
$P_1*V_1=P_2*V_2$

If P1=99.92kPa and V1=10.8mL, while P2=5.8kPa and V2=185.92mL (Based on *TABLE 2*, data from 1st and 2nd lines)

$$P_1*V_1=99.92*10.8=1080$$

$$P_2*V_2=5.8*185.92=1080$$

Both sides equal 1080 which means that Boyle's law has just been proven mathematically.

RAW DATA FOR BOYLE'S LAW (FROM THE LAB NOTEBOOK)

Name: [redacted]
Student number [redacted]
Date: [redacted]

Boyle's Law (2nd experiment)

For this experiment we will be using a gas pressure sensor and a syringe. The two variables we will be using is pressure and ~~temprature~~ volume. The units we will be using are "mL" for the volume and "kPa" for the pressure. Additionally, volume is considered independent while pressure is considered dependent. (*)

Me and my partner have chosen a volume of 10 mL, but because of the space inside the pressure sensor itself it should be 10,8

(*) The reason for this is because volume can be changed using the syringe while the pressure is dependant on what the volume is set at.

[redacted]

Me and my partner have started data collection and by 6 ~~[illegible]~~ different volume measurements we have concluded with a table of our variables:

V (mL)	P(kPa)	
10,8	99,92	
5,8	~~185,92~~	185,92
15,8	~~68,0~~	68,42
3,8	225,58	
8,8	~~124,70~~	124,77
10,8	100,49	

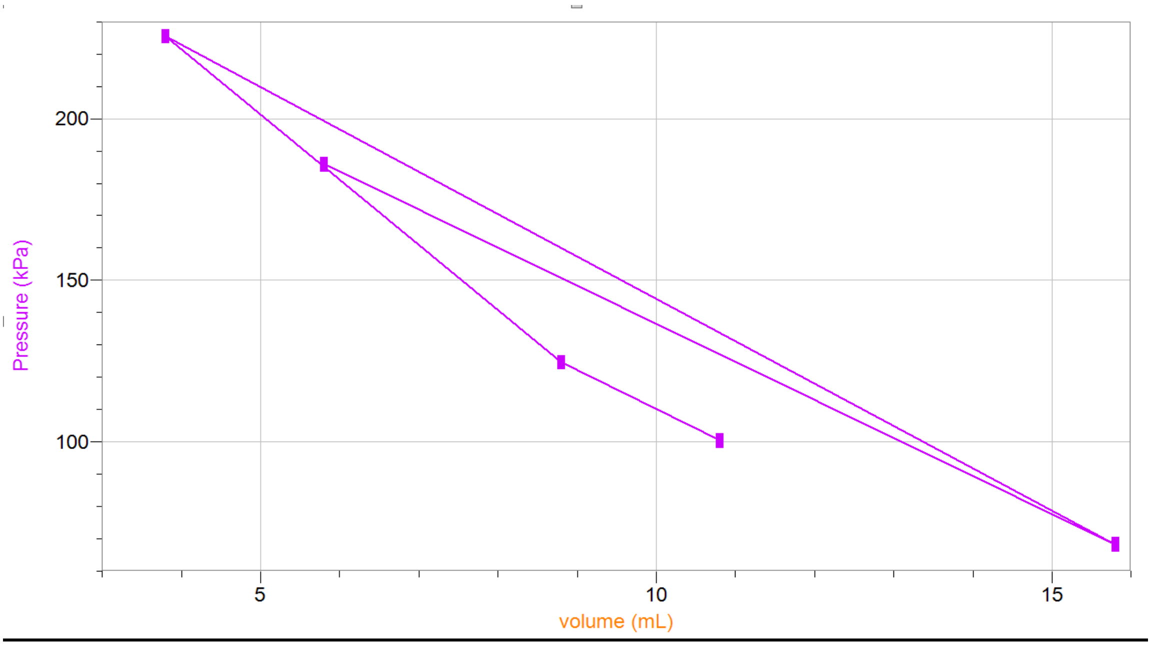
Me and my partner obsered that the ~~closer~~ ~~we~~ more we pushed and pulled the plunger the higher the pressure became.

We finished the first run and started the second

V(mL)	P(kPa)
10,8	100,17
6,8	161,22
11,8	91,15
12,8	83,71
14,8	72,67
16,8	63,60
10,8	98,92

[redacted]

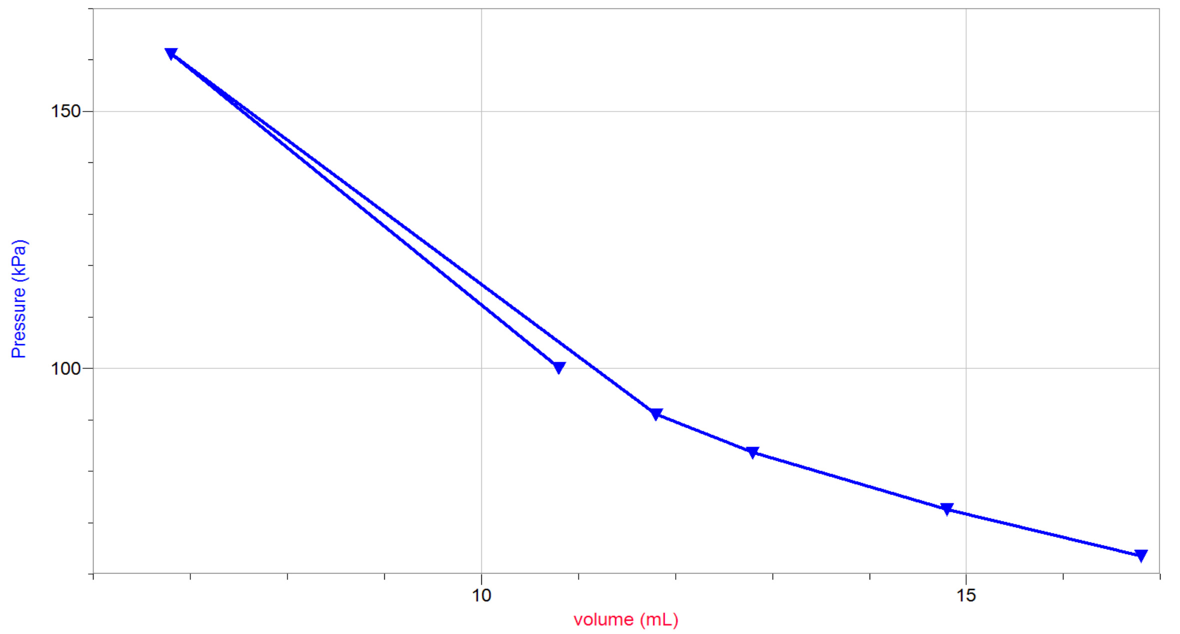
GRAPHS FOR BOYLE'S LAW (LOGGERPRO)



Graph A (1st run)

This graph depicts the connection of a gas's volume to the pressure of itself.

	Run 1	
	volume (mL)	Pressure (kPa)
1	~~10.80~~	~~99.92~~
2	5.80	185.92
3	15.80	68.42
4	3.80	225.58
5	8.80	124.77
6	10.80	100.49



GRAPH B (2nd run)

This graph depicts the connection of a gas' volume to its pressure

	Run 2	
	volume (mL)	Pressure (kPa)
1	10.8	100.17
2	6.8	161.22
3	11.8	91.15
4	12.8	83.71
5	14.8	72.67
6	16.8	63.60
7	~~10.8~~	~~98.92~~

DISCUSSION

In the end of both experiments, I was satisfied with my results because of the precision and closeness some measurements were to each other.

In addition, I realized that the well-known scientists Charles and Boyle were dealing with the same equation (Formula 1 from the introduction) but in different forms, the entire time, just as shown below:

- $P \times V = n \times R \times T \Rightarrow P \times V/T = n \times R \Rightarrow V/T = n \times R/P \Rightarrow V/T = n \times R/P = A$ (Charles Law, P=constant)

- $P \times V = n \times R \times T = K$ (Boyle's Law, T=constant)

Where A and K are constants too.

CONCLUSION

The gas law theories were proven in simple ways by experimentations in the laboratory and mathematically as well. It can make one think of how maths, chemistry and real life are closely interconnected with one another and how deep the concept of these laws may go. In the end, surprisingly, not many errors occurred throughout the process.

Introduction sources:

[1] Raymon Chang,"General Chemistry The Essential Concepts", Chapter 5.3, Page 136, The McGraw-Hill's Companies, Published in 2008

[2 and 3] URL: https://www.chemguide.co.uk/physical/kt/otherlaws.html

Author: Jim Clark (2010)

Assessment Criteria for Planning the Boyle's Law Investigation

(to be completed BEFORE lab and given to TA)

TA Name:	[redacted]	**Names of Students in Group:**	**a.** [redacted]
			b. [redacted]
		Date:	[redacted]
Criteria:	**Marks Possible**	**Assessment**	
		Self	**TA**
1. Identify the problem and state it clearly in a way that can be tested.	**1**	1	1
2. Use proper apparatus, techniques and safety precautions.	**1**	1	1
3. Materials are easily available.	**1**	1	1
4. Plan to vary only one independent variable at a time.	**1**	1	1
5. Controls on other variables are clearly stated.	**1**	1	1
6. Measurement errors are minimized by appropriate procedures or apparatus.	**1**	1	1
7. The methods are clear enough to be followed by other students.	**1**	1	1
8. No invalid assumptions are made.	**1**	1	1
9. Reagents that need accurate measurement are identified.	**1**	1	1
10. Lab trials are stated.	**1**	1	1
11. Repeats are stated.	**1**	1	1
12. Chemistry vocabulary is used correctly.	**1**	1	1
13. Limitations of the experimental design are described.	**1**	1	1
TOTAL:	**13**	13/13	13/13 :)