Experiment 1. Verification of Boyle's Law

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Introduction:

Gas is a complex state. Solids and liquids have a fixed volume at a given temperature, where this is not the case for a gas. Gases themselves are energetic and do not have a fixed shape, they take up the volume of a given container or room. It is difficult to describe a real gas due to the molecules constantly moving, colliding and interacting with one another. This is why Robert Boyle experimented with the volume and pressure of a gas to create a part of the Ideal Gas Law. through his experiment he discovered that the pressure and volume of a gas are inversely proportional to one another. This law allows anyone to predict the behaviour of real gases.

The ideal gas law is a combination of three experiment/laws, Charles's law, Boyle's law and Avogadro's law. Charles's experiment kept pressure and the amount of mols constant, and saw that temperature is *directly* proportional to the volume. Therefore when one increases so does the other. Boyle, kept temperature and the amount in mols constant, and discovered that the volume and the pressure is *inversely* proportional to the other. When one increases the other decreases. Avogadro found that when you keep the pressure and temperature constant, the amount of a gas and the volume of a gas is *equally* proportional to one another. The combination of these three laws created the *Ideal Gas Law*.

$$PV = nRT$$

**P*=pressure, *V*= volume, *n*= amount in mols, *T*=temperature in Kelvins or degree celcius, *R*= universal gas constant*

An Ideal gas's volume is relative to the volume of a container. It is also assumed that the molecules of the gas do not attract or repel one another, and therefore the energy of a gas molecule is constant. There is no such thing as an ideal gas, although some common gases behave similarly to one (O_2, H_2, N_2). An ideal gas exhibits linear relationships among volume, pressure, temperature and the amount of mols in the gas.This equation is designed for use of gases at low density and high temperatures. Specifically in this lab we will look at the relationship between pressure and volume of an "ideal gas".

Purpose:

The purpose of this experiment id to see the relationship between pressure and volume of a gas, at fixed amount and temperature. This will proceed by trapping air in a 20ml syringe that is connected to a Gas Pressure Sensor (GPS). The plunger of the syringe will be moved in order to change the volume of the container, and the pressure will be gauge using the GPS.

Safety:

Wear eye protection at all times.

Materials:

- LabQuest 2
- Vernier Gas Pressure Sensor
- 20ml gas syringe
- USB stick (flash drive)

Procedure:

1. Gather materials
2. Set up the GPS to LabQuest 2, turn it on and create a new file.
3. Set the syringe plunger to 2.5 ml, and then attach it to the GPS (there is an extra 0.8 ml of gas at the end of the pressure sensor, therefore this will need to be added to the volume) Be sure not to overturn the syringe, as it can strip the GPS.
4. Set up the data collection on labquest 2 by going to mode, and changing it to *Events and Entry.* Enter the independent variable as Volume (ml).
5. Collect pressure and volume data by; beginning at the initial volume (2.5ml + 0.8ml), wait for pressure to stabilize and hit *Keep* on the LabQuest 2, and enter the data.
6. Increase the volume by 2.5ml, by pulling the plunger out. Wait for the pressure to stabilize, hit keep and input the data.
7. Repeat step six another 7 times, increasing the volume by 2.5ml each time.
8. When finished, move the plunger back to the initial volume, wait for it to stabilize, keep and input the data once more and then stop the data.
9. Decide on which initial volume to keep, remove the other by going to the table and hit strike through. (a line should pass through to show removal of data.)
10. Examine and Analyze the graph variables to determine the mathematical relationship between the pressure and volume. Click on Analyze, then Curve Fit of the variable and choose a function that fits best. Return to the graph screen and the function will be plotted with the data obtained.
11. Transfer the data to the USB stick.
12. Clean up the lab bench area by putting the equipment in the proper places.

Observations/Data:

Table1: The Effects that Increasing the Volume in a 20ml Syringe have on Pressure

Volume (ml)	Pressure (Pa)
~~2.5+0.8 (3.3)~~	~~100.91~~
5.0+0.8 (5.8)	46.07
7.5+0.8 (8.3)	32.97
10.0+0.8 (10.8)	24.72
12.5+0.8 (13.3)	19.51
15.0+0.8 (15.8)	16.76
17.5+0.8 (18.3)	14.97
20.0+0.8 (20.8)	12.92
2.5+0.8 (3.3)	81.49

Data Analysis:

In order to solve for Boyle's law constant, it is assumed that temperature and the amount of mols was fixed the entire time. Therefore the gas constant can easily be found by using the Ideal gas law. (PV=nRT). Since the mols and the temperature is constant we can ignore them in the equation.

$PV = R$ $\quad$ $PV = R$ $\quad$ $PV = R$ $\quad$ $PV = R$

$(3.3ml) * (81.49Pa) = R$ $\quad$ $(5.8) * (46.07) = R$ $\quad$ $(8.3) * (32.97) = R$ $\quad$ $(10.8) * (24.72) = R$

$R = 268.917$ $\quad$ $R = 267.206$ $\quad$ $R = 273.651$ $\quad$ $R = 266.976$

$R = 2.7 * 10^2$	$R = 2.7 * 10^2$	$R = 2.7 * 10^2$	$R = 2.7 * 10^2$
$PV = R$	$PV = R$	$PV = R$	$PV = R$
$(13.3) * (19.51) = R$	$(15.8) * (16.76) = R$	$(18.3) * (14.97) = R$	$(20.0) * (12.92) = R$
$R = 259.483$	$R = 264.808$	$R = 273.951$	$R = 268.736$
$R = 2.6 * 10^2$	$R = 2.6 * 10^2$	$R = 2.7 * 10^2$	$R = 2.7 * 10^2$

The constant was calculated for every interval. It can be assumed that the constant is $2.7x10^2$ ml*Pa, when the system is at constant temperature and amount.

The mathematical relationship of Boyle's law, is that when and ideal gas is at a fixed temperature and a fixed amount of mols, the pressure and temperature are inversely proportional to one another. This means that as one increases the other decreases. This is seen in this experiment when the syringe volume was increased, there was a decrease in the pressure. This makes sense because the air molecules have more space to move freely, therefore there is less energy acting on the walls of the syringe. Therefore we can assume that $PV=2.7x10^2$, only if the temperature and amount inside the container stay constant. Due to this relationship we can assume that every time the syringe volume increase by 2.5ml, the pressure decreased by roughly $\frac{1}{2.5}$ Pa. The relationship is exponential, but it is to a power of a fraction therefore it is decreasing (you cannot have a negative exponent).

In order to account for human error, the initial volume/ pressure was taken twice. Once and the beginning of the experiment and once at the end. It is always a good idea to measure the independent and dependent variable a second time just to account for simple mistakes. The second reading of the temperature was used, since it was more suitable for the rest of the obtained data.

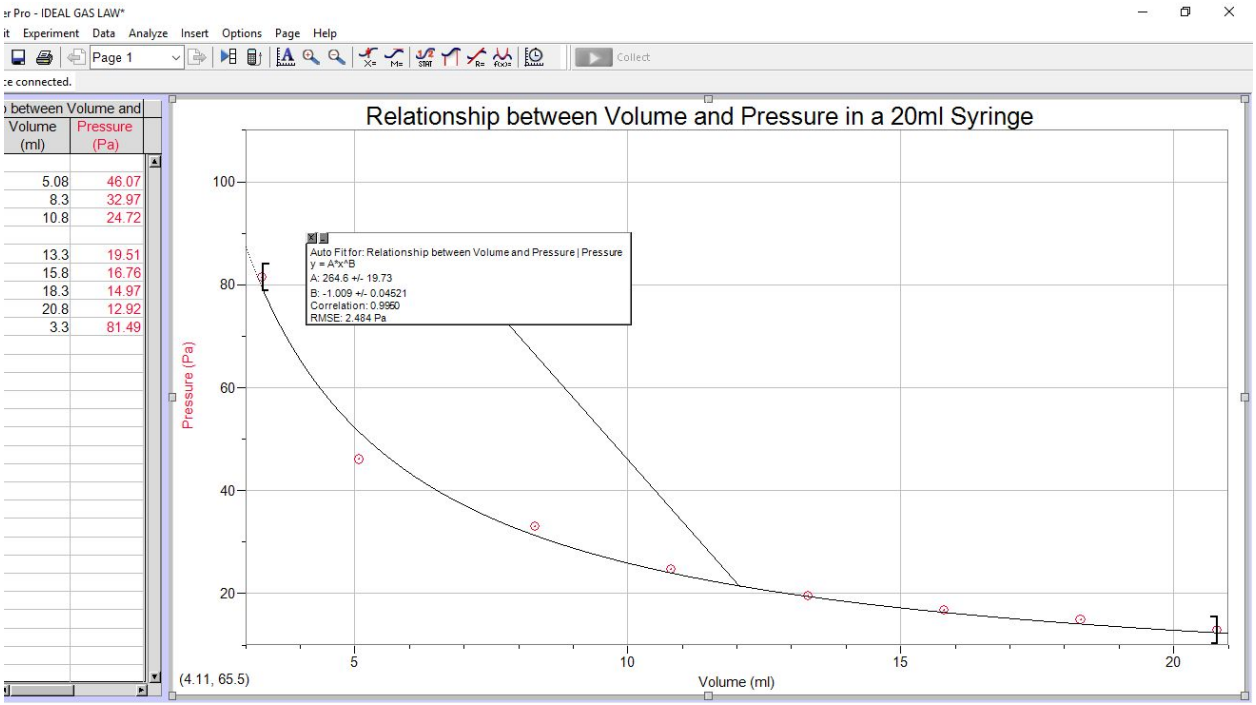
For Boyle’s law to be correctly used, the temperature and amount of mols needs to be kept constant the entire time. These variables were taken into consideration by making sure the syringe was correctly on the GPS, as well as the syringe was checked for leaks prior to being attached to the Gas Pressure Sensor. Keeping the temperature constant the entire time was more difficult because in order for the syringe to be moved hands were involved. Considering the temperature of the room, the human hand had a significantly higher temperature. Due to the GPS, if the plunger was let go it would go back to the initial volume, therefore hands were on the system at all times. This could have possibly increased the temperature throughout the experiment, thus not keeping the temperature constant. This could have possibly caused variations in the volume and pressure. This would cause variations because increasing the temperature of a system will also increase the volume of that system (objects expand when heated or condense when cooled). This is one of the experimental errors that was found throughout the experiment.

Conclusion:

There was sources of error with keeping the temperature constant throughout the entire experiment due to the difficulty of keeping the volume of the at the specific level. Another source of error would be from human. Specifically when inputting the data, a comma was accidentally hit instead of a decimal point. This was easily erased on LabQuest 2, but could have affected the graph if not caught.

All in all it is concluded that Boyle's law is true. It is verified by this experiment, because the volume of the air in the syringe is inversely proportional to the pressure. This occurred throughout the entire experiment, and kept fairly constant through the calculations. There was slight variation of the gas constant with interval five and six. This could have been due to the fact that the pressure was not stable when inputting the data. Besides the small calculation errors, the law stayed true, and the pressure decreased when the volume was increased. Although the percentage error is huge, compared to the theoretical value of R, the relationship between the volume and pressure is constant therefore it can be concluded that the experiment proved the law.

$$\%error = \frac{eperimental - theoretical}{theoretical} \times 100$$
$$= \frac{2.7 * 10^2 - 8.314}{8.314} \times 100$$
$$= 3147\%$$



② Cora Weller Verifacation of Boyle law

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Procedure Sept. 14/1

6- Examine/Analyze graph of varibles to determine math relationships
↳ ~~[illegible]~~ "Analyze" → Curve Fit ▾ (variable) → choose a function that Best fits.
↳ return to graph screen + fxn will be plotted to data
→ try different functions.

7) Clean up Lab bench + work area
↳ keep locker organized.

Observations:

RMSE: 2.15

Table 1:

	Volume ~~independent~~	Pressure ~~Dependent~~
3.3	~~2.5ml + 0.8ml~~	~~100.41~~
5.8	5.0ml + 0.8ml	46.07
8.3	7.5ml + 0.8ml	32.97
10.8	10.0ml + 0.8ml	24.72
13.3	12.5ml + 0.8ml	19.51 *
15.8	15.0ml + 0.8ml	~~15.40~~ 16.76
18.3	17.5ml + 0.8ml	~~14.30~~ 14.97
20.8	20.0ml + 0.8ml	12.92
3.3	2.5ml + 0.8ml	81.49

power

$y = Ax^B$

$= 264.6x^{-1.00}$

Next Log

$y = A \ln(B \cdot x)$

$= -34.214 \ln(0.0392$

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PV=nRT   Verification of Boyles law

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Chemistry Lab #1

Constant = Temperature + # moles

Independent = ~~Pressure~~ Volume } b/c we are changing the vol of syringe.

Dependent = ~~Volume~~ + Pressure

In order to verify Boyles law, these have been chosen because they are directly correl[illegible] together.

Procedure

1- Gather materials →

2- Set up the Gas pressure Sensor to Lab Quest 2.
↳ Connect GPS to Lab Quest 2, turn it on and Create a new file.
↳ Move syringe plunger to 2.5ml and attach to GPS.
* Careful not to strip threading.

3- Set up data-collection on LabQuest 2
↳ Mode → Change mode to events w/ Entry.
↳ enter variable + units (volume=ml, pressure

* Remember that there is 0.8ml of volume in the end of the GPS ∴ needs to be added.

4- Collect Pressure + Volume Data by:
↳ Starting at initial Volume (2.5ml + 0.8ml)
↳ Stabalize pressure and "keep" the reading + enter data
↳ Change volume by 2.5ml by moving plunger wait to stabilize "keep" +
↳ Final Volume Move Back to initial V + stop data.

5- Decide which initial Volume to keep

References

Lavieri, Silberberg, Patricia, Venkateswaran, Chemistry: The Molecular Nature of Matter and Change 2CE, Ch. 4, McGraw-Hill Ryerson Limited, 154-160, (2016.)

Jewett, Serway, Physics for Scientists and Engineers with Modern Physics 9CE, Ch.19.5, Brooks/Cole, 615, (2014).

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