
VERIFICATION OF IDEAL GAS LAW

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Introduction:

As opposed to solids and liquids, gases do not have fixed volumes. In the ideal gas law, pressure, volume, and temperature are described as a relationship. Pressure (variable: P), Volume (variable: V), and Temperature (Variable: T). All of which have an interdependent relationship with the other, meaning that if one variable is given the other remaining variables could 'theoretically' be determined. The relationship between the three variables have been mathematically quantified through these specific formulae entitled 'The Ideal Gas Laws':

- Boyle's Law: $P_1V_1 = P_2V_2$
- Charles's Law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Relationship Between Pressure & Volume:

Boyle was able to discover the relationship between pressure and volume through a series of ingenious and extremely intricate experiments. Using a J-shaped glass tube and pouring mercury down into separate ends of it he was able to vary the atmospheric pressure inside the system and discover how the fluctuating pressures effected the volume of gas trapped inside the tube. Through this method he established that the volume of a given gas is inversely proportional to the external pressure of said gas.

$$V \propto \frac{1}{P} \quad \llbracket P \uparrow V \downarrow \rrbracket$$

Relationship Between Temperature & Volume:

The experiment that eventually led to the discovery of 'Charles's Law' was remarkably similar to that of Boyle's. In the way that both experiments involved the utilization of glass J-shaped tubes. The relationship between volume and temperature was established quantitatively through heating the J-shaped tube and observing the behavior of the gases within the tube. When done so correctly, the data expressed a proportional relationship between temperature and volume.

$$T \propto V \quad \llbracket T \uparrow V \uparrow \rrbracket$$

However, one should note that each of the gas laws communicate the affect of one variable to another, only when the remaining variable (the outlier) remains constant. Meaning, that for every calculation involving one of the gas laws an assumption must be made; the assumption being that the variable not seen in the equation is constant (unchanging). [I.e. when using Boyle's law, one must assume that the temperature is constant and when using Charles law, the other assumption is the pressure is constant].

Limitations of the ideal gas law are indefinitely inherent. The ideal gas laws are only accurate so far as the surrounding and conditions are *ideal*. This is when gas particles are at low pressure and high temperature. Moreover, we know that real gases don't behave the same way as ideal gasses.

References

Luder, W.F. "Ideal Gas Definition." *Journal Of Chemical Education* (1968): 351. Document.

Procedure:

Charles's Law:

- As described in the lab manual (Ref)

Boyle's Law:

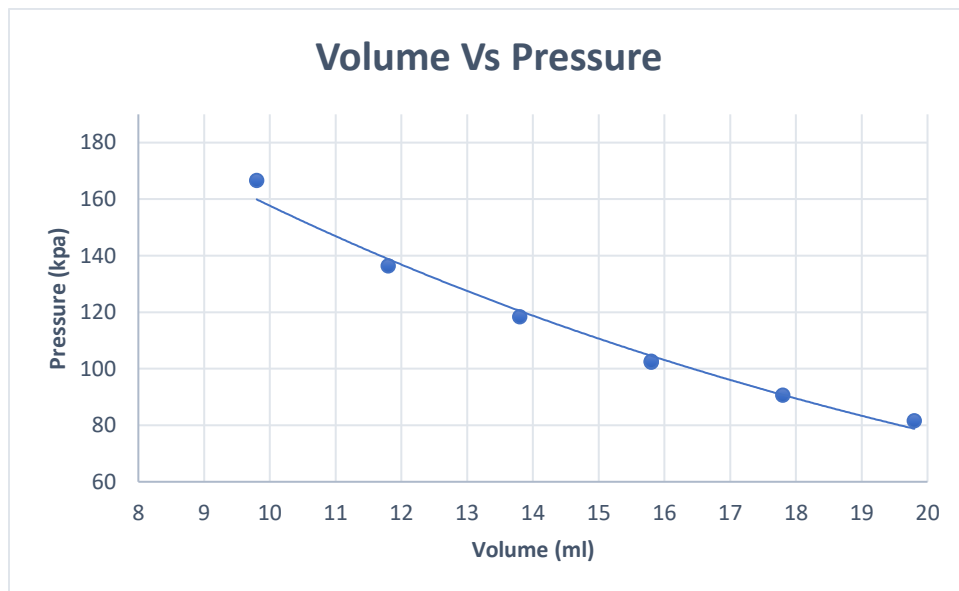
Equipment- Plastic Plunger, pressure sensor, and Labquest2.

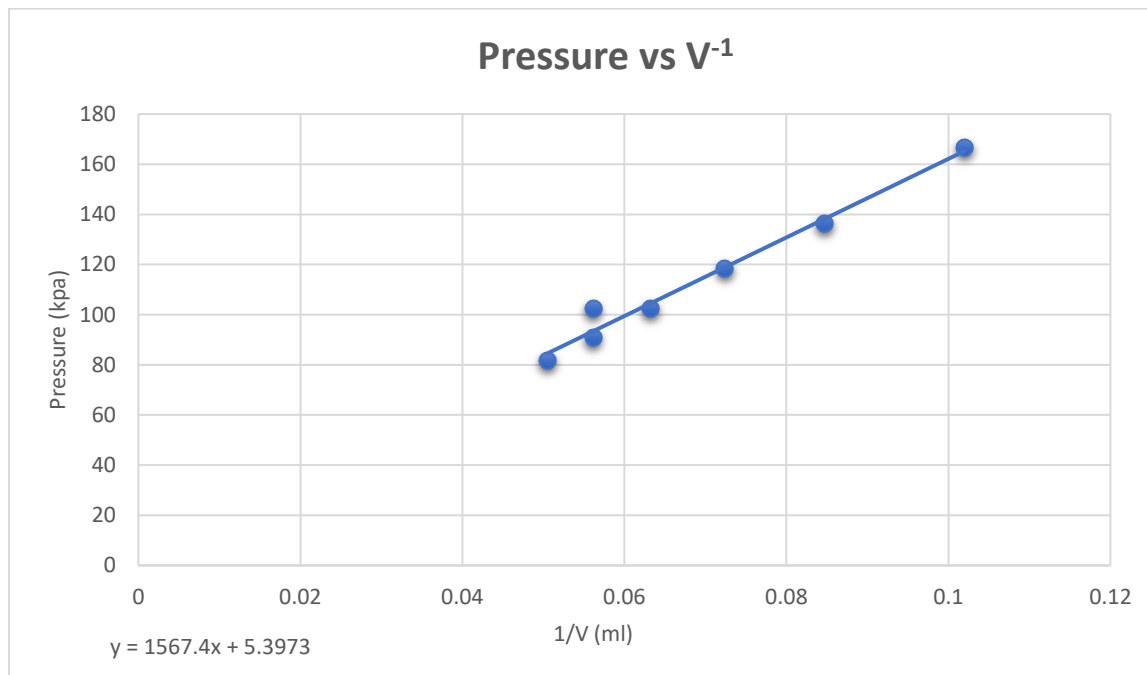
- Connect Pressure sensor apparatus into Labquest2 tool.
- Edit settings inside Labquest2 to collect desired data
- Ensure pressure gauge/plunger reads 15ml, then proceed to connect it into the pressure sensor
- Vary volume inside syringe, make sure to observe and note output reading of pressure sensor inside LabQuest
- Use the graph function within labquest2 to illustrate data
- Click stop to conclude data collection; then exit program.
- *Clean Area*

Data:

Set 1. Data and Results for The Verification of Boyle's Law

Volume (ml)	Pressure (kpa)
15.8	102.3
13.8	118.32
11.8	136.38
17.8	90.68
19.8	81.61
9.8	166.65
15.8	102.61





Set 2. Data for Verification of Charles's Law

Temperature Of Boiling Water: 100°C

Temperature of Ice Bath: 3.7°C

Volume of Cold Water: 46 ml

Initial Volume of Air: 151 ml s

Calculations:

$$V_1 = 154$$

$$V_2 = V_1 - V_{CW} \rightarrow (151 - 46) = 105 \text{ ml}$$

$$T_1 = 100^\circ\text{C}$$

$$T_2 = 3.1^\circ\text{C}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{154}{100} \neq \frac{105}{3.1}$$

Calculated theoretical V_2

$$\left(\frac{154}{100}\right)(3.1) = V_2 = 4.774$$

Error:

$$\%error = \left(\frac{V_1}{T_1} - \frac{V_2}{T_2}\right) \times \left(\frac{T_1}{V_1}\right) \times 100\%$$
$$\left(\frac{154}{100} - \frac{105}{3.1}\right) \times \left(\frac{100}{154}\right) \times 100\% = -2099.4\%$$

Data Analysis:

Calculating Boyle's constant:

Constant is derived through the inverse plot of Volume and Pressure.

$$y = mx + b$$

Linear Equation for tangent line used: $f(x) = 1567x + 5.3973$

Variable $m = \text{Boyles Constant} = 1.567 \times 10^3$

- 3) The importance of having multiple readings for the dependent variable of the same value of independent variable is to ensure if the pressure stays constant even after changing the volumes and returning to the same volume. Therefore, it can be used to analyze the accuracy of the Vernier gas pressure sensor.
- 4) The variables that are required were temperature and number of moles. These two variables need to maintain as constant. Both these variables were certainly taken into consideration! The temperature of the room was kept constant at room temperature. The number of moles were kept constant by keeping the syringe connected inside of the Vernier gas pressure sensor. If the syringe was to be disconnected, there would have been a loss in moles resulting in the decrease of the number of moles.

Discussion:

There are quite a few sources of error in this particular lab.

Astronomically high percent error for the Charles law experiment. Are perhaps due to the conditions the lab was performed in. As earlier mentioned the formula/ relationship only describes the properties of **ideal gas**. And the conditions required to assess a substance as an ideal gas is that it be subject to an extremely high external pressure and low temperature. Conversely, our substance (the air) was only subject to about 1 atmospheric pressure ($\approx 101.325 \text{ kpa}$) and a relatively high temperature of 25.6°C . Another more practical source of error might have occurred upon the removal of the flask from the ice bath. Perhaps the flask wasn't removed correctly and the pressure difference voided all application of Charles Law. The condition that states that pressure must remain constant during the experiment.

However, regarding the experiment of validating Boyle's Law, the results surely did not deviate too much from the initial expectations. As expected, plotting the external pressure applied to a gas against its volume produces a graph with a rational relation. The rational graph does well in visually showcasing the effect of applied pressure on the volume of gas:

- The graph shows that the product of corresponding Pressure and Volume values results in a constant; the constant being denoted as 'Boyle's Constant' = 1.567×10^3 *
- V(volume) is inversely proportional to P(Pressure)
- V is directly proportional to $1/P$

Overall the data collected through this experiment did a wonderful job of confirming the theoretical knowledge of Boyle's Law. Through this data we conclude that at constant temperature, the volume occupied by a gas is inversely proportional to the applied pressure.

Conclusion:

In conclusion, the values collect from both experiments were not completely identical to the theoretical expectations and one of the experiments yielded results that weren't even within an imaginable range of values. Nevertheless, both experiments were still a success in the sense that they quantitatively verified the ideal gas laws. More so, the Boyle experiment though.