Lab Report Boyle's Law

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1 Aim

In this experiment, we aim to validate Boyle's Law, an important law that contributed to the Ideal Gas Law in general, stating that when the temperature of a given mass of confined gas is constant, the product of its pressure and volume is also constant.

2 Apparatus

- gas pressure gauge
- a syringe that can be connected to the pressure gauge
- steel ruler

3 Procedure

1. Setup:
   (a) Obtain a syringe with a plunger, a steel ruler, and a pressure gauge.
   (b) Ensure the syringe is airtight and has no leaks.
2. Initial Measurements:
   (a) Fill the syringe with a fixed volume of air (e.g., 10 mL) and ensure the piston is at a starting position.
   (b) Use the steel ruler to measure the initial length of the air column in the syringe.
3. Applying Forces:
   (a) Gradually exert a compression force on the piston to decrease the volume of the air column.

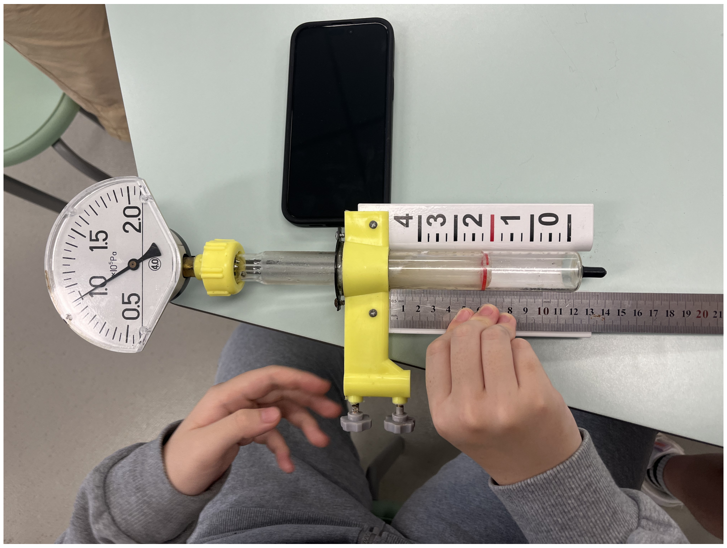


Figure 1: Recording the length of air column and its corresponding pressure.

(b) Record the pressure using the pressure gauge after each adjustment.

4. Data Collection:

   (a) Repeat the process, varying the length of the air column (and therefore the volume) by adjusting the piston.

   (b) Collect at least six sets of data, ensuring you record both the length of the air column and the corresponding pressure.

5. Data Recording: Create a table with two columns: one for the length of air column and one for the corresponding pressure readings.

4 Data Collection

By collecting the length of air column and the corresponding pressure, we recorded a total of 8 groups of data, listed in Table 1 The average of the trials is taken to reduce random error and the average values for the length of air column and pressure are listed in Table 2.

Consider the smallest scale of the ruler and the pressure gauge, length of the air column measured by the ruler should have an uncertainty of $0.025 \approx 0.03$. And the pressure gauge has a relatively large uncertainty of $0.025 \times 10^5 \approx 0.03 \times 10^5$Pa.

5 Data Processing

To validate the Boyle's Law, to prove that when the temperature of a given mass of confined gas is constant, the product of its pressure and volume PV is also constant, we need to plot the relation between P and $1/V$. As $PV = k$ where k is the constant, $P = 1/V \cdot k$.

In this experiment, since the area of the air column is fixed, we have $P = k \cdot 1/L$.

The uncertainty of $1/L$, $\Delta(1/L)$ should satisfy the relation below:

$$\frac{\Delta L}{L} = \frac{\Delta(1/L)}{1/L}$$
$$\implies \Delta(1/L) = \frac{\Delta L}{L} \cdot (1/L).$$

Trial	**Length of Air Column (cm)**	**Pressure** $\times 10^5$Pa
1	6.34	1.17
2	6.37	1.18
3	6.36	1.15
1	5.00	1.16
2	4.98	1.16
3	4.98	1.14
1	3.88	1.45
2	3.92	1.42
3	3.91	1.42
1	2.91	1.70
2	2.88	1.70
3	2.92	1.69
1	6.72	0.84
2	6.69	0.83
3	6.68	0.86
1	7.93	0.83
2	7.94	0.81
3	7.95	0.83
1	8.65	0.67
2	8.64	0.71
3	8.66	0.68
1	9.43	0.68
2	9.44	0.66
3	9.44	0.67

Table 1: Raw data table of the length of air column and pressure.

Length of Air Column (cm)	Pressure ($\times 10^5$Pa)
6.35	1.17
5.00	1.16
3.90	1.44
2.90	1.68
6.70	0.85
7.95	0.83
8.65	0.69
9.45	0.67

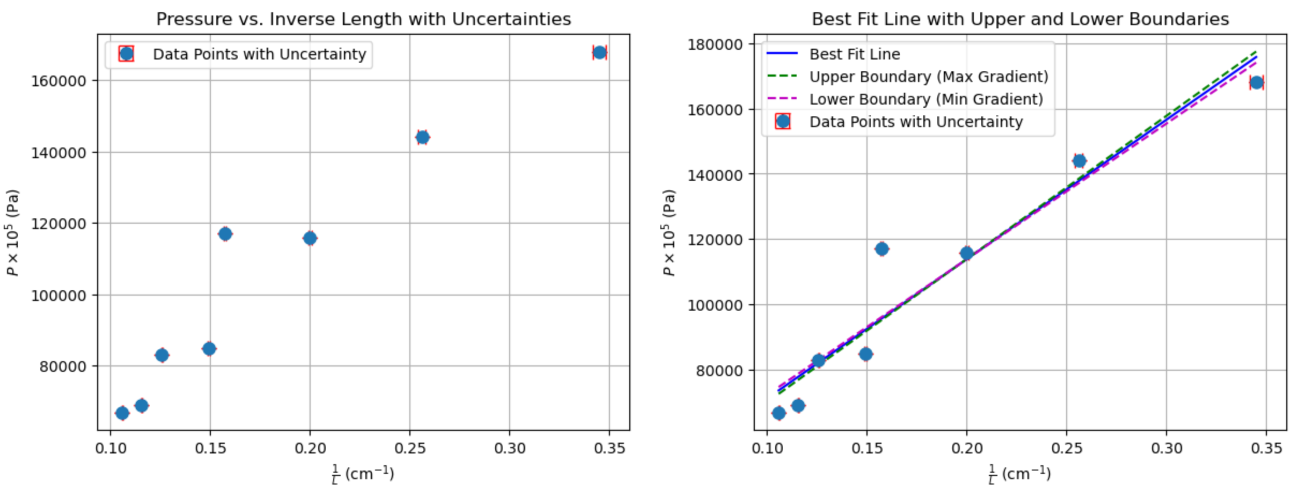
Table 2: Raw data table of the length of air column and pressure.

The processed data of P and $1/L$, along with their uncertainties is shown in Table 3

$1/L$ (cm^{-1})	$P \pm 0.025$ ($\times 10^5$ Pa)
0.1575 ± 0.0006	1.17
0.200 ± 0.001	1.16
0.256 ± 0.002	1.44
0.345 ± 0.003	1.68
0.1493 ± 0.0006	0.85
0.1258 ± 0.0004	0.83
0.1156 ± 0.0003	0.69
0.1058 ± 0.0003	0.67

Table 3: The processed data table of P and $1/L$, with their uncertainties.

The processed data points are plotted in Figure 2 showing the relationship between P and $1/L$, with uncertainties.



(a) Scattered Points Plot

(b) Best-Fit, Maximum Gradient, Minimum Gradient Lines Included

Figure 2: The diagrams show the relationship between the pressure P and the inverse length of air column $1/L$.

6 Conclusion and Evaluation

6.1 Conclusion

The experiment aimed to validate Boyle's Law, which states that the pressure of a fixed mass of gas at constant temperature is inversely proportional to its volume. While the general trend aligns with the law – showing that pressure increases as the volume decreases – not all data points fall perfectly on the best-fit line or within the range of upper and lower boundary lines, as shown in Figure 2. This discrepancy suggests some deviation from the ideal behavior predicted by Boyle's Law.

One likely reason for these deviations is the uncertainty in pressure measurements, as the equipment used may have introduced significant error in the readings. Additionally, the work done during the compression of air could have caused an increase in the gas's temperature. Since Boyle's Law assumes constant temperature, even a small temperature rise could affect the relationship between pressure and volume, making the proportionality constant k vary across measurements.

6.2 Evaluation

Accuracy and Uncertainties

- The measuring tool is *outdated* and not accurate, which may explain the deviation of some data points from the expected trend.
- The equipment (e.g., pressure gauge) may not have been sufficiently precise for the range of pressures measured.

Effects of Temperature Changes The compression of gas involves work, which can increase the temperature of the gas, violating the constant-temperature assumption. This change can influence the results and cause the proportionality constant k to vary.

Possible Improvements

- Use a more precise pressure gauge with smaller uncertainties to reduce measurement errors.
- Allow the gas to return to ambient temperature between measurements to ensure isothermal conditions.
- Increase the number of data points to better capture the trend and account for measurement variations.

Further Considerations

- Conduct the experiment under carefully controlled thermal conditions or use slow compression to minimize heating effects.
- Compare results with ideal gas predictions to evaluate the extent of deviations due to non-ideal behavior in real gases.