An experimental study on Boyle's law and Gay-Lussac's law

Aim

The aim of this experiment is to verify Boyle's law by investigating how pressure and volume relate and also verifying Gay-Lussac's law by investigating the relationship between volume and temperature.

Introduction

Both Boyle's and Gay-Lussac's law base themselves on the proportion of two variables and always have a third constant factor. In fact Boyle's law refers to when at a constant temperature and with a fixed quantity of gas, pressure is inversely proportional to volume. Therefore $p \propto \frac{1}{V}$ and $p \cdot V = constant$ which gives an isothermal curve so the curve showing the relation between pressure and volume of a given mass of gas when the temperature is constant. Instead Gay-Lussac's law refers to when at a constant volume, pressure and temperature are proportional to each other. The temperature must always be considered to be in Kelvin and the absolute zero, so the minimum possible temperature, is -273 K. The formula for Gay-Lussac's law is $\frac{p}{T} = constant$.

Instruments and equipment

- Pressure sensor —> specificity ± 0.01 kPa ; Range 0.00 < 200.00 kPa
- Syringe —> specificity ± 1 ml ; range 20 ml
- Thermometer —> specificity ± 0.1°C ; range < 400°C
- Electrical heater
- 2 bakers of different dimensions

Safety issues

- Pay special attention when using the electric heater and the hot water to prevent burning yourself or damaging the equipment.
- Avoid surpassing the maximum range of the pressure sensor to prevent the braking of it.

Procedure for Boyle's law

- Align the piston rubber pad to the fifth millilitre on the graduated scale as accurately as possible
- Block the volume of the syringe by turning the lever at the top of it
- Attach the pressure sensor with the adaptor to the tip of the syringe and check that all the instruments are correctly working
- Measure the value at 5 ml to be able to see afterwards if the syringe correctly worked
- Take measurements of the pressure for each ml starting from 3 ml until reaching 15 ml. Help yourself by closing the lever to fix the volume each time that you take a measurement, in this way the degree of precision will be higher as it will be easier to keep the volume steal while reading the value.

Procedure for Gay-Lussac's law

- Fill almost completely a baker with room temperature water. Pay attention to the fact that afterwards you should be able to almost completely submerge the smaller baker.
- Insert the smaller baker inside of the baker with water and place the whole on the electric heater which should be still off.
- Insert inside of the smaller baker both the thermometer and the pressure sensor. To make the experiment work, the baker should be sealed, so use a rubber pad to completely seal the baker in the way that no air can go in or out of it.
- Start both the automatic temperature and pressure recorder and the electrical heater.
- Wait until the pressure reaches tot kPa and turn off the electrical heater.
- When both the pressure and temperature have stabilised stop the recording.

Results - Boyle's Law

Volume (ml ; ± 1)	Pressure (kPa ; ± 0.01)
3	165,13
4	130,25
5	102,72
6	89,20
7	78,60
8	70,49
9	62,97
10	56,41
11	52,37
12	48,33
13	45,43
14	42,20
15	39,43

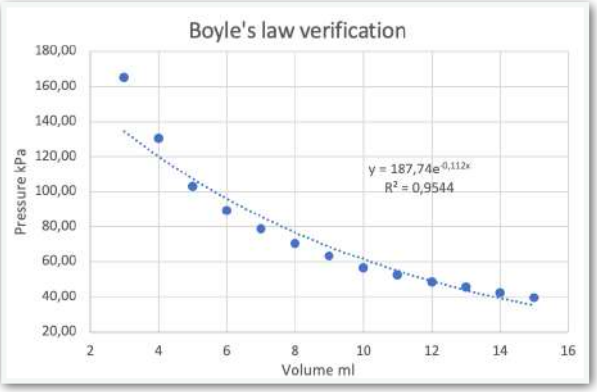
Pic. 1 —> syringe attached to pressure sensor

Results - Gay-Lussac's Law (Sample)

Pressure (kPa ; ± 0.01)	Temperature (°C ; ± 0.1)
110.2682681	60.62451645
110.2051456	60.37451645
110.142023	60.06201644
109.9487102	59.81201644
109.5620845	58.93701642
109.3687717	58.62451642
109.2385814	58.37451642
109.2385814	57.81201641
109.1715137	57.4995164
109.0452686	57.1870164
108.9150783	56.93701639

Pic. 2 —> two bakers on top of electric heater

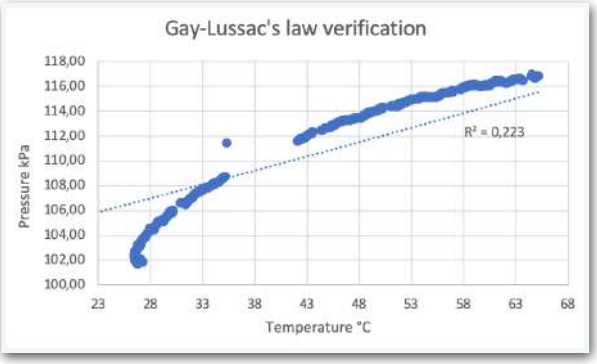
Analysis - Boyle's Law



Graph 1 —> Boyle's law results

-From the graph it can be noticed that there is a very strong inverse relationship between pressure and volume as Boyle's law tells.
-The R^2 value is of 0,9544 and so confirms the fact that the two variables have an exact inverse proportionality.

Analysis - Gay-Lussac's Law



Graph 2 —> Gay-Lussac's law results

-From the graph it can be noticed that there is a correlation between Temperature and Pressure, even though it is not strong.
-The R^2 value is of 0,223 and as it is a very low value for the Pearson coefficient, the results do not fully confirm Gay-Lussac's law

Conclusion

In conclusion both Boyle's and Gay-Lussac's were verified and partially verified as the relationships between $p \propto \frac{1}{V}$ and $p \cdot V = constant$ for Boyle's Law were confirmed by the results as the R^2 value of 0,9544 is very near to 1 which represents exact inverse proportionality, and for Gay-Lussac's law stating that $\frac{p}{T} = constant$ was instead partially confirmed, as the value of the R^2 is 0,223, which so does not validate the direct proportionality between pressure and temperature, even though it can be seen that the data follow the correct pattern, so the law is partially verified. For this type of experiment the degree of uncertainty does not necessitate to be very high as the two laws can be confirmed even without very accurate measurements, even though it would be better to have more sensitive instruments, especially regarding the syringe, to obtain a stronger relationship. In addition, regarding Gay-Lussac's law, a better sealed baker would be more suitable.

Bibliography

- Physics for the IB diploma, sixth edition
- Picture 1 —> syringe attached to the pressure sensor
- Picture 2 —> two bakers on top of the electric heater
- Graph 1 —> Boyle's law results
- Graph 2 —> Gay-Lussac's law results