Gas Thermometer - Group 26

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1 Introduction

The purpose of this experiment is to construct a gas-thermometer. This thermometer will be used to determine the temperature at absolute zero.

2 Theory

The ideal gas law states that:

$$PV = NkT$$

It follows that $P \propto T$ when V and N are constant. This implies:

$$P = 0 \Leftrightarrow T = 0$$

Therefore, we suppose we are able to find the temperature at absolute zero by finding $P = 0$.

3 Method

Three beakers are filled with water. The water in the first beaker glass is brought to a boil, and ice cubes are added to the second beaker to cool it down to near freezing. The water in the third beaker glass is kept at room temperature. In order to get the water boiling faster, aluminium foil is put on top of the beaker glass.

The measuring setup is constructed by plugging a conical flask and connecting it to a t-piece connector. The two other ports of the connector are connected to a syringe and a Vernier pressure sensor, respectively.

The pressure in the conical flask is measured and the airtightness of the system is checked. Using the syringe, the pressure is adjusted to 100 kPa.

The conical flask is lowered into the boiling water in the first beaker and both the pressure in the flask and the temperature of the water are measured. The flask is then moved to the ice-bath in the second beaker and the procedure is repeated. These measurements are repeated thrice.

In order to obtain data points between the cooled and boiling water, the conical flask is moved to the beaker at room temperature. This beaker is then heated and the pressure in the flask is measured at various temperatures throughout the heating process.

The mean pressure and temperature from the repeated measurements in the cold and boiling beaker is computed alongside the error of the mean, which will be used to estimate the uncertainty of the measurements.

A calibration line is calculated using these two datapoints, while a line is fitted to the other datapoints using linear regression.

Both models are used to calculate the temperature at absolute zero and their results are compared to the theoretical value.

4 Results

We've estimated the error of the temperature and pressure using the standard deviation of the repeated measurements of the boiling water and the freezing water. It came out to be $\Delta_T = \pm 0.7$ K and $\Delta_P = \pm 0.11$ kPa.

The data for pressure and temperature is assembled to the following graph:

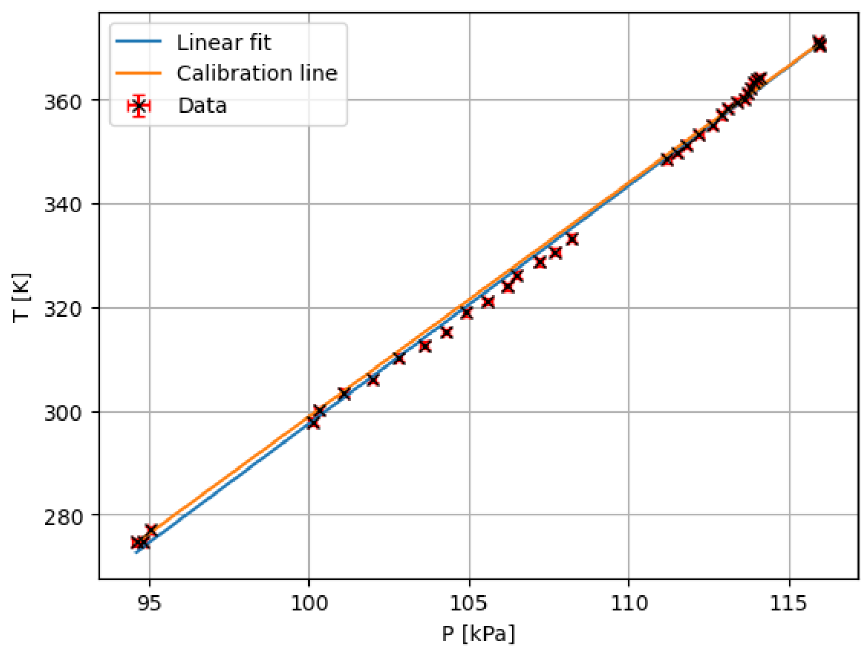

Figure 1: Data, a linear fit and a calibration line. The fit has a reduced chi-squared value of $\chi^2_{red} \approx 2.43$.

The linear regression was fitted with the following model:

$$T(P) = \alpha \cdot P + \beta$$

The computed parameters of the linear regression can be found in the table (tab. 1) beneath.

Slope (α)	$(4.58 \pm 0.02)\ \frac{\mathrm{K}}{\mathrm{kPa}}$
Intercept (β)	$(-161 \pm 3)\ K$

Table 1: Parameters and their values

From this we see, that the temperature at absolute zero is found to be: $\beta = (-161 \pm 3)\ K$. Since the expected value at absolute zero is $0\ K$, this gives a z-value of 53.

5 Discussion

The Vernier pressure sensor disconnected during the experiment, so we were forced to switch apparatus. Because of this we created another system with a new amount of molecules, since we had to detach the tube. In the new system, we calibrated the pressure to be the same as the latter, and based on the ideal gas law, we should have had the same amount of molecules given they both started at room temperature.

We measured the pressure at the minima and maxima of the result. By waiting for the curve to flatten, the temperature inside and outside the bottle came into an equilibrium. If the measurement of the pressure was taken before equilibrium the pressure inside the bottle would not correspond to the right pressure at that temperature. We know that we stopped measuring before the equilibrium was reached, and this has to do with the long time it would take the system to get there. We decided it was okay to stop, when the change in pressure seemed nearly flat, but this was done by eye.

Due to time constraints, we were only able take measurements at a single starting pressure. This makes our single calibration line useless, as it was supposed to be used with other calibration lines to give a indication for the temperature at absolute zero. This would be possible, given the theory stated in the beginning, which tells that all lines should agree on the absolute zero. Given the calibration lines (that we not have), we would have been able to determine the temperature at absolute zero without any thermostats. This is due to our information about the temperature of boiling water and freezing water, which would give us enough information to get a estimate of the value by having a lot of lines determined from only two data points each. Also due to time constraints, we were not able to determine, whether there is hysteresis in the system or not.

Our prediction does not agree with the theoretical value of absolute zero, as shown by the high z-value. Our hypothesis is that this is because of the extra air in the tubes that connect the pressure sensor to the flask. Only the air in the conical flask is heated/cooled, but the pressure inside the flask is affected by the air in the tubes. This would also explain why our prediction for the temperature at absolute zero is lower than expected, since the conical flask would need to be cold enough to counteract the pressure from the warm air in the tubes.

This issue could be mitigated by using shorter tubes, finding a way to submerge the entire system in the water or placing a pressure sensor inside the conical flask.

6 Conclusion

The predicted value for the temperature at absolute zero was found to be $(-161 \pm 3)\ K$ while the theoretical value was $0\ K$. The two values do not agree, as their associated z-value is 53. The experiment should be repeated with the adjustments mentioned at the end of section 5, which the biggest fault mentioned is, that we did not calculate for the extra gas in the tubes connecting the conical flask with our apparatus for measuring pressure.