Triple point of water

Project-oriented Physics Lab for Undergraduate Students

Physics Lab ETH zürich

Idea of the Experiment

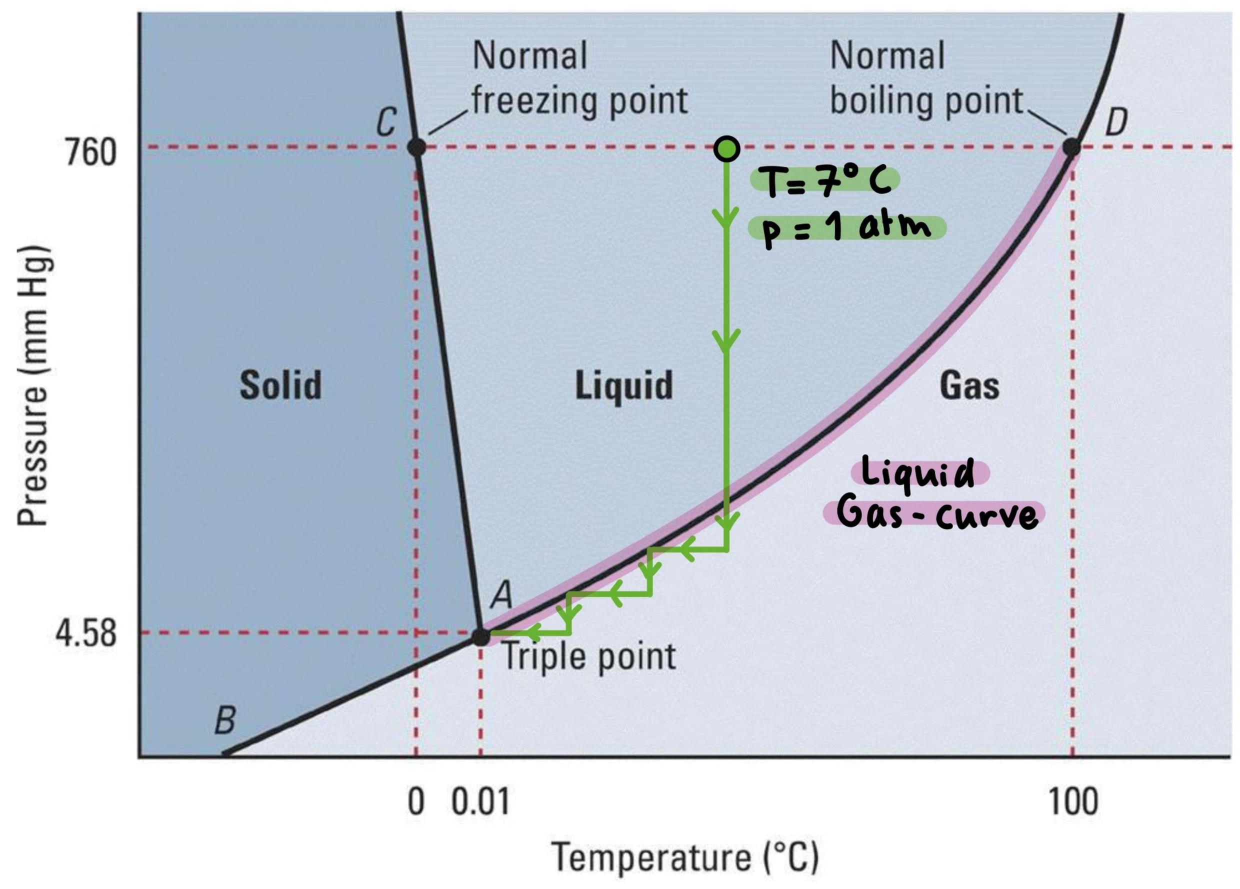
Goal: Determine the Triple Point of Deionized Water

The triple point refers to the point in a **p-T diagram** where three phases coexist in thermodynamic equilibrium.

Various principles in thermodynamics describe this effect, out of which the **Clausius-Clapeyron equation** describes the vapor pressure curve:

$$\frac{dp}{dt} = \frac{L}{T\Delta V}.$$

When the vapor pressure curve is met, the **pressure** must be decreased at a precise rate to stay on the curve without overshooting the triple point. This leads to a decrease in **temperature**, as the open valve releases vapor, which causes a loss of heat. Thus, we move along the curve is a **stair-like manner**.



We started with water at 7°C and atmospheric pressure and then approximately followed the green curve.

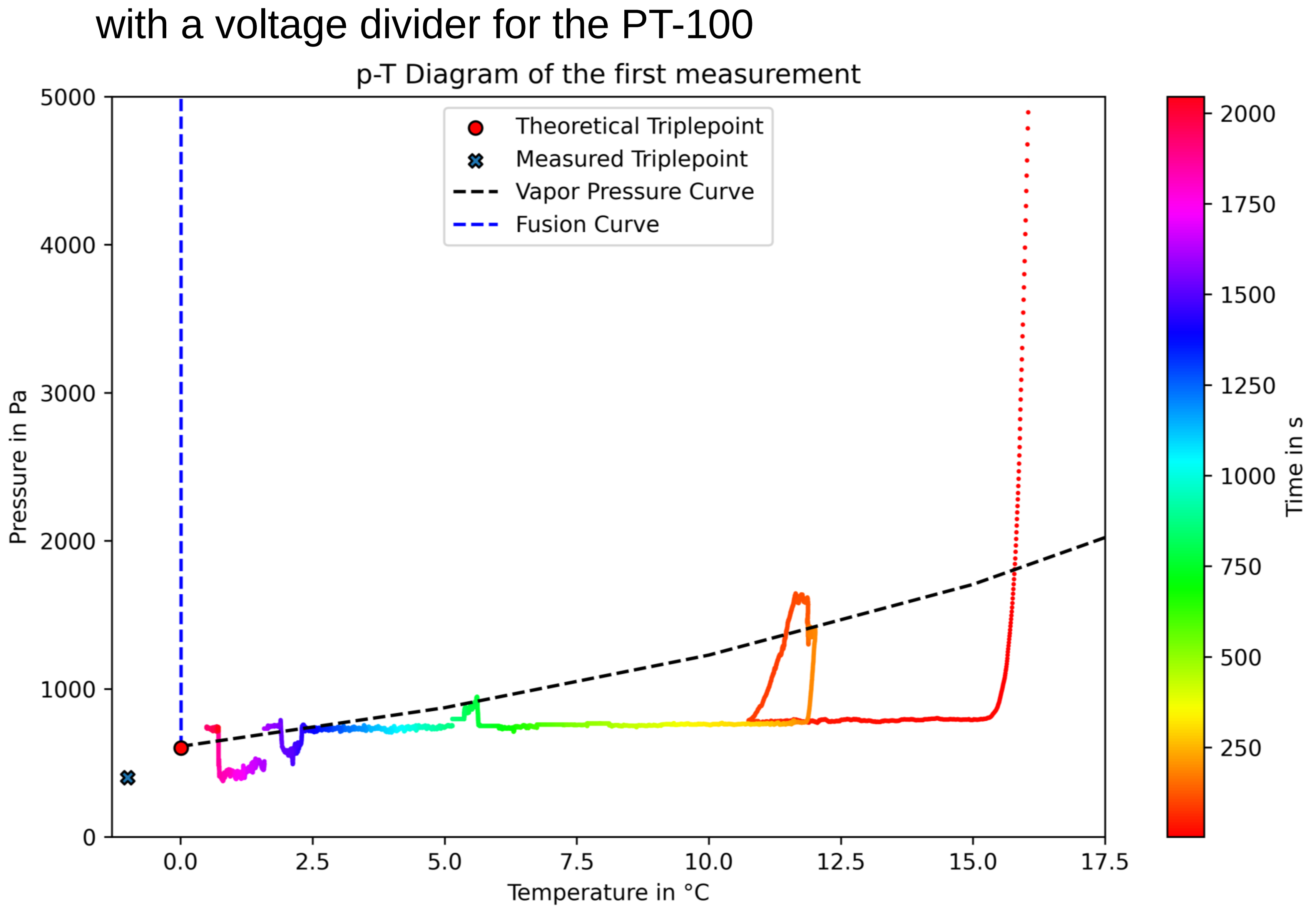
Results

The state of the water was monitored through the see-through lid of the chamber. We determined the triple point to be at **-1°C** at **4.0mbar** with our first measurement, and **-1.5°C** at **6.4mbar** with our second.

These points correspond with the appearance of tiny ice shards on the boiling water's surface. These values however noticeably deviate from the literature value of **0.01°C** at **6.4mbar**.

Inaccuracies:

- Subjective interpretation in determining the triple point
- Inaccurate temperature sensors and software difficulties
- Challenges in controlling the system's temperature and pressure due to water's high heat capacity
- Additional resistance introduced by the necessity to build a circuit with a voltage divider for the PT-100



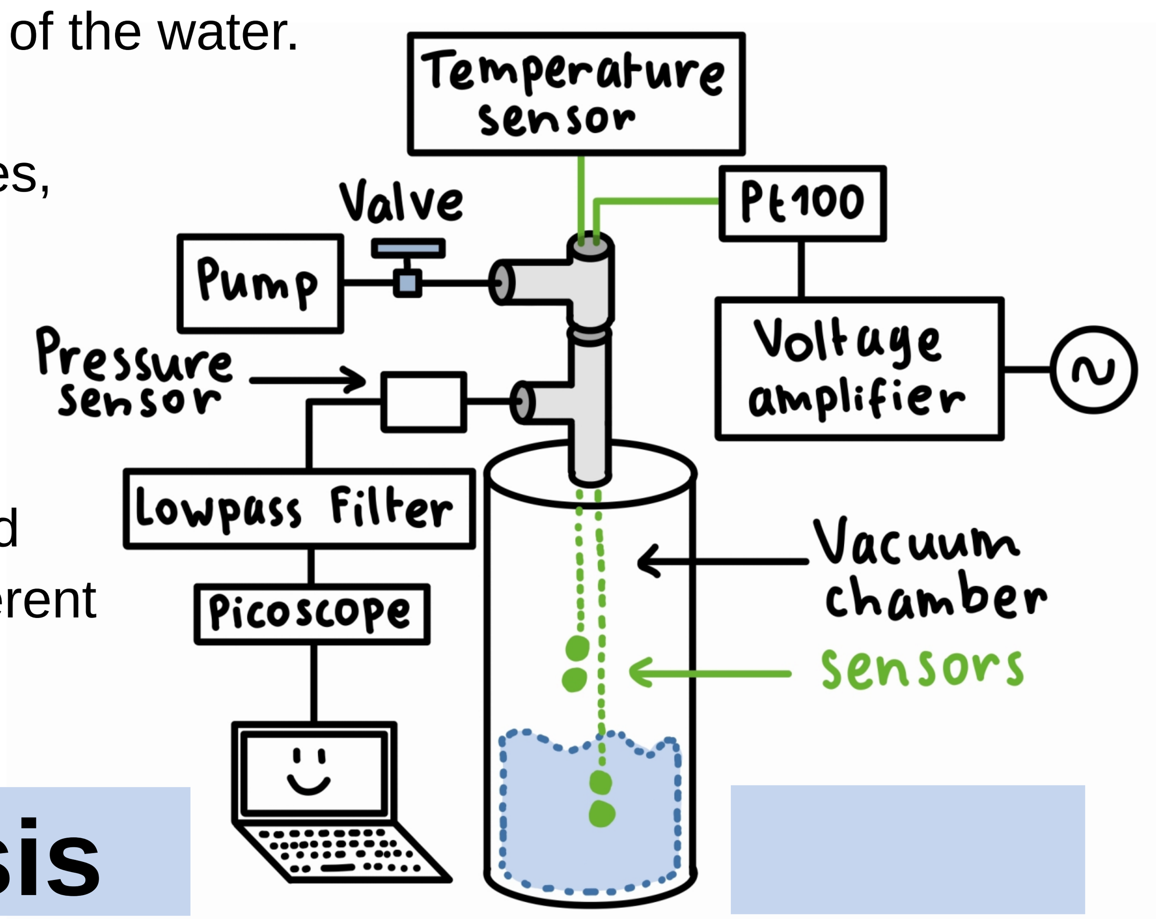
Setup

The **vacuum pump** is used to reduce the pressure inside the chamber. The rate of this reduction can be variated using the **valve**.

Two sets of **temperature sensors** were used: two PT-100 and two K-type sensors, one of each type was respectively placed in the liquid and the vaporous phase of the water.

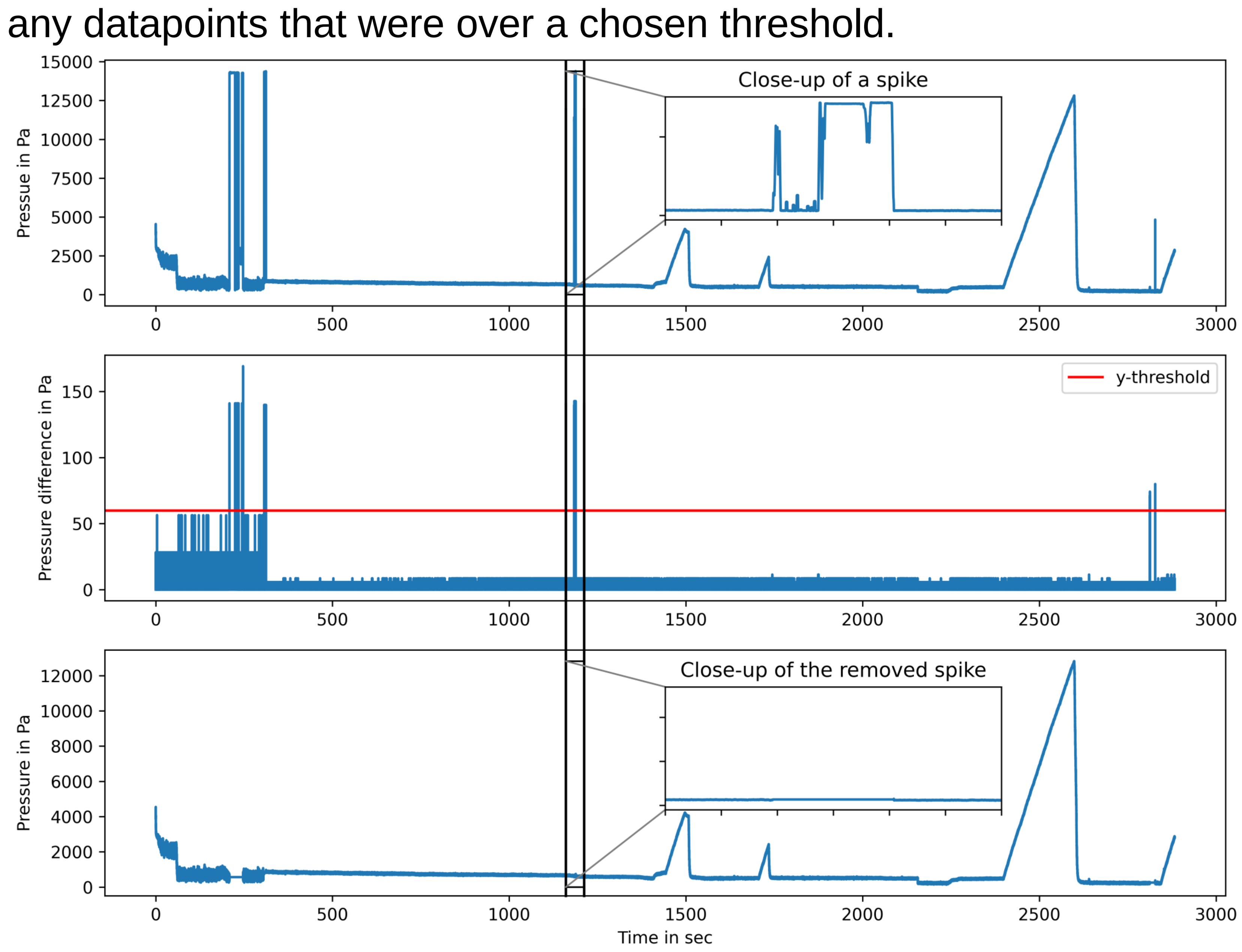
With the use of both types, we expected more accurate results.

The **lowpass filter** is used to reduce unwanted noise created at the different measurements.



Data analysis

The circuit we used was self-soldered and a loose contact resulted in the recorded data being very **noisy**. We thus had to filter out many spikes. For this, we calculated the discrete derivative and removed any datapoints that were over a chosen threshold.



Additionally, we calculated a **moving average** of approximately 7 seconds over the first dataset and 0.1 seconds over the second.

The data after the noise filtration can be seen in the p-T diagram bellow.

We determined the triple point with the K-type sensors, which is why the measured point in the diagram does not lie on the collected data points.