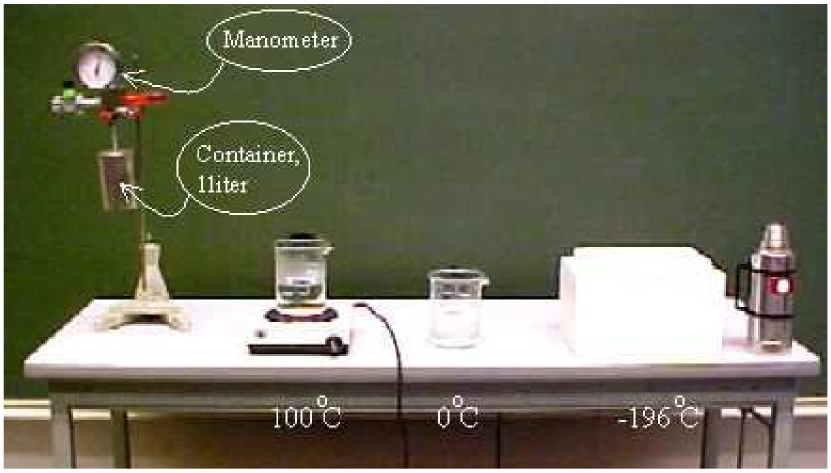
Constant volume gas thermometer

Aim: To show how the ideal gas temperature scale is defined.

Subjects: 4A10 (Thermometry)

Diagram:



Equipment:

- One liter container, filled with H_2 and a pressure-meter mounted to it.
- Clamping material.
- Glas beaker, 2 liter, filled with boiling water.
- Hot plate.
- Glass beaker, 2 liter, filled with ice-water.
- Polystyrene box that can be filled with liquid notrogen.
- Prepared pT-graph on overhead sheet (x-axis: +100^{o}C to -300^{o}C; y-axis: 0 to 1.5bar).

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Presentation: First, the container is dipped into the beaker with ice-water. The pressure reduces and after settling, the pressure is read.
Then the container is immersed into the glass beaker with boiling water. The pressure rises and settles after some time: the pressure is read.
Finally, the container is placed in the polystyrene box and then liquid nitrogen is poured into it. While the container cools down the liquid nitrogen boils vigourously, quieting when the boiling point of the liquid nitrogen is reached. Then the pressure is read.
The three measured points are fitted in the graph on the overheadsheet and it can be observed that the three measured points show a linear relationship, intersecting the T-axis at around -270°C.

Explanation: The product of pressure and volume of a gas depends strongly on the temperature of that gas. So perssure or volume can be used as a thermometric quantity. In this demonstration pressure is used as such and V is kept constant (one liter). So we speak of a constant volume gas thermometer. $pV=nRT$, making $T=(V/RT)p$, and so an appropriate temperature scale is defined as $T=Ap$. For calibration only one constant is needed now. So when we measure pressure at two temperatures and draw a straight line between them we can read from this graph the temperature corresponding to any other pressure ($T_2/T_1=p_2/p_1$). Extrapolating this graph, we see that there is a hypothetical temperature (-273,15°C) at which the pressure would become zero. This extrapolated zero-pressure temperature is used as the basis for a temperature scale: p is directly proportional to this Kelvin temperature (see Figure1)

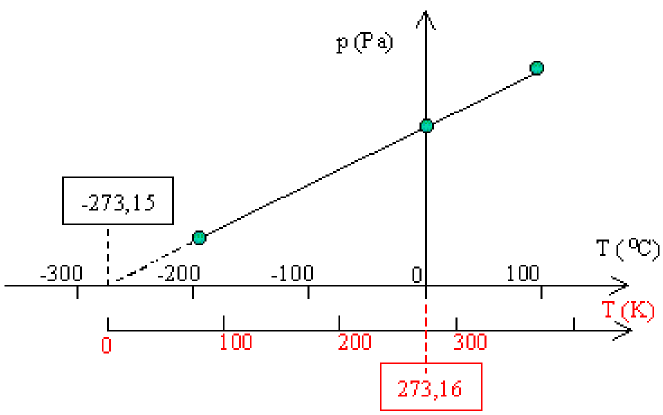

Figure 1

To complete the definition of T one point of the graph is specified. For this the triple point of water is chosen. This occurs at 0.01°C and this point is *defined* as having the value 273.16K (see Figure1).

Remarks:

- Instead of the beaker with ice-water we sometimes use the roomtemperature as a point of measurement. Then we start the measurement with this point and so we save time in doing the demonstration.

Sources:

- Mansfield, M and O'Sullivan, C., Understanding physics, pag. 263-265 and 277
- Young, H.D. and Freeman, R.A., University Physics, pag. 463-464

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