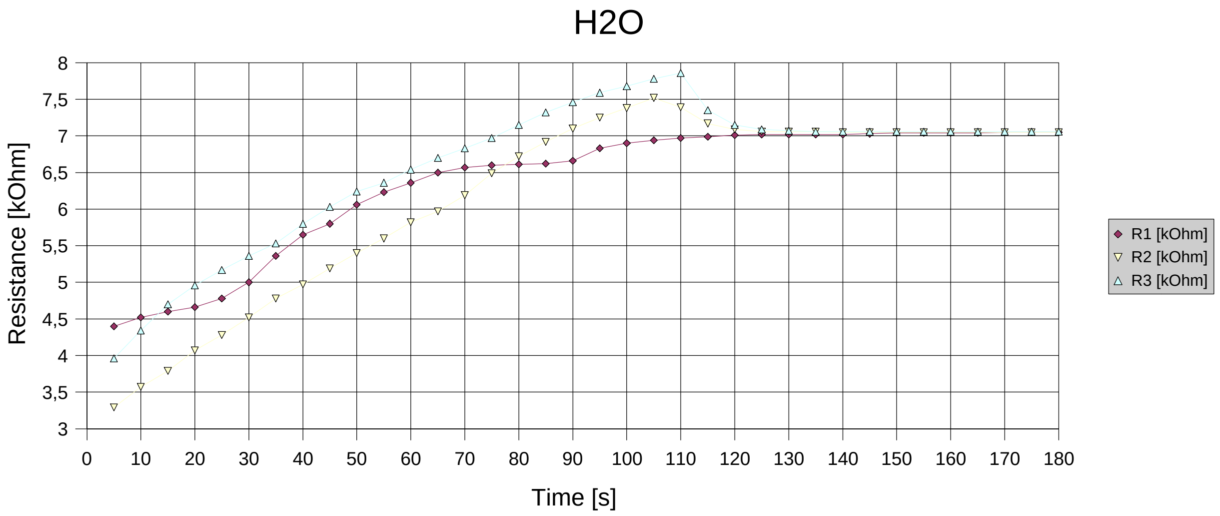
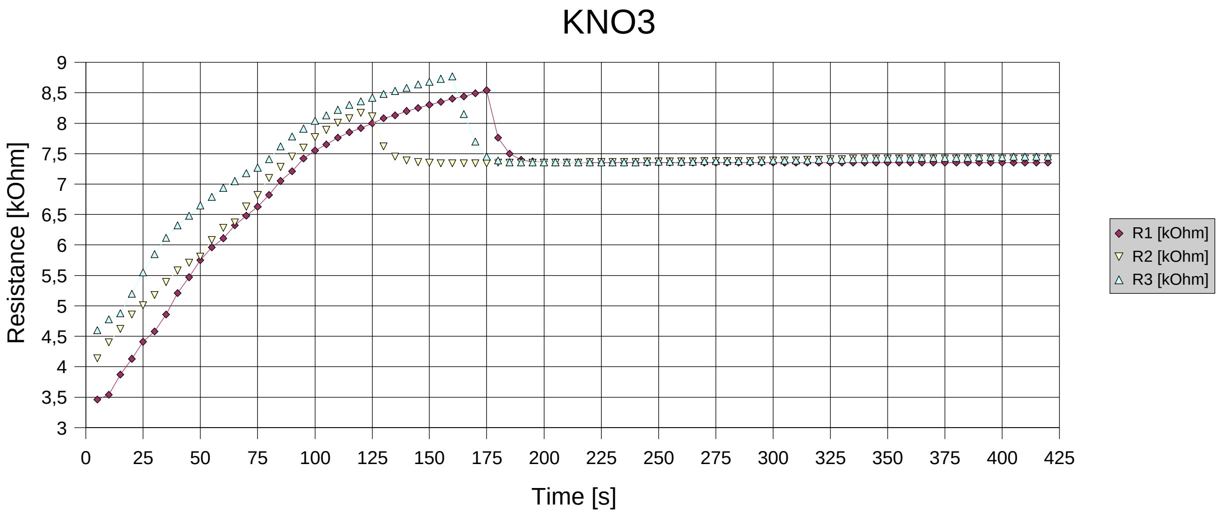
Physik-Praktikum: DIS

Results

The Process of Freezing

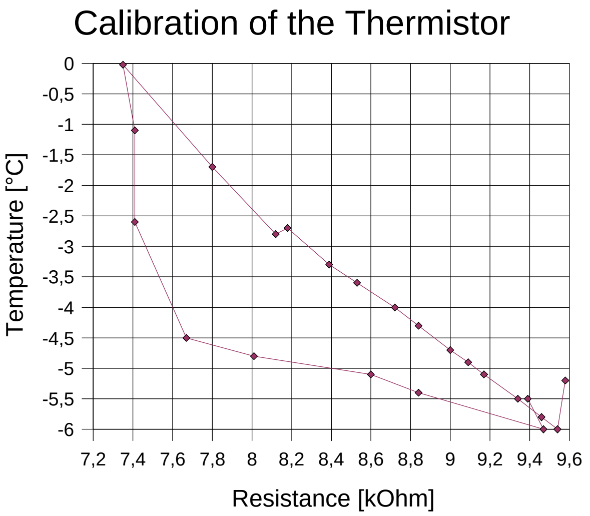


The graph of the first measurement does not reach a maximum; actually, this should not happen, maybe the temperature distribution was not homogeneous, so the thermistor did not measure the right temperature. At the following measurements, we stirred more intensively, and it did not happen again.



Calibration of the Thermistor

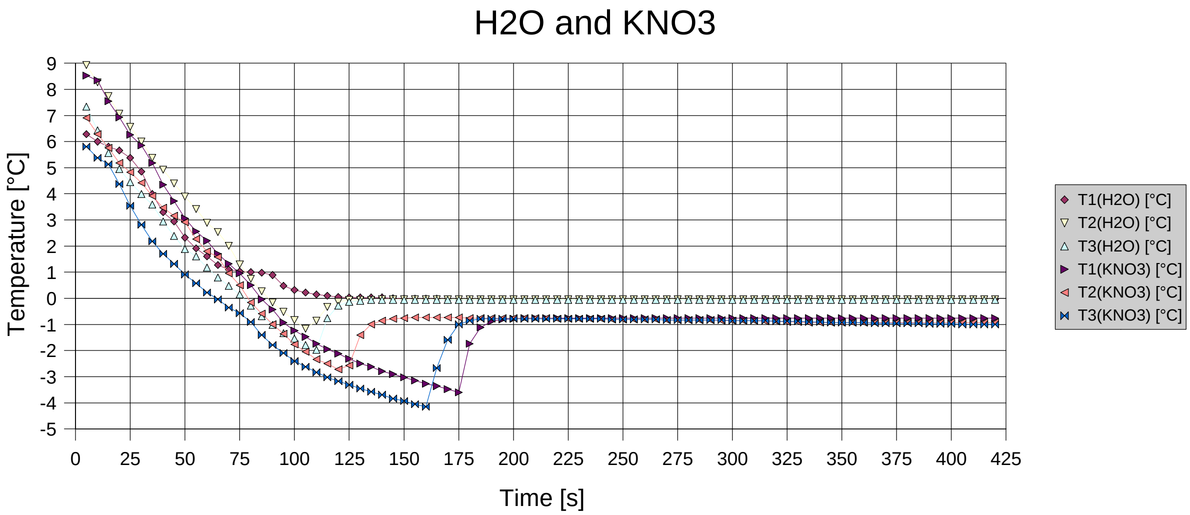
To calibrate the thermistor, the temperature and the corresponding resistance of the thermistor are measured at different temperatures in the range between -6 and 0 °C. The adjustment of the temperature is quite a problem: we can only add water or ice/salt to raise or to lower the temperature, so it is likely that it does not change as fast/slow as expected. At first, we started at -6 °C and added water to reach 0 °C; because our measurements did not look sensible, we added ice to cool the mixture down again.



As one can see, some of our measurements are indeed crap. By taking only the measurements that lie on the lower-right end of the upper line of this diagram and by assuming a linear relation between resistance and temperature, we get the following function for the linear fit:

$$T\left(R\right) = -2.39\,\frac{°\mathrm{C}}{\mathrm{k}\ \Omega}\cdot R + 16.79\ °\mathrm{C}\ .$$

With this relation, we can redraw the diagrams (combined in one diagram):



One can clearly see the different freezing points for distilled water and the KNO_3-solution. Also, that the temperature of the water after reaching the freezing point stays constant meanwhile the temperature of the KNO_3-solution slowly decreases (because the solution becomes more and more concentrated because the solvent freezes out) is clearly to be seen.

The reason that the graphs are shifted in horizontal direction in respect to each other is that our measurements have begun after the test tube had been put into the cooling mixture and the thermistor had been installed, which happened sometimes faster and sometimes slower; in this time, the water/solution in the test tube was already cooling down, before we started measuring.

$\Delta\ T_G = \left(0.72 \pm 0.015\right)\ \mathrm{K}$ (calculated from the mean values of the freezing points of water/solution)

Number of Dissolved Particles

$M_1 = M_{H_2O} = 18.0153\ \mathrm{kg/kmol}$; $m_1 = 19.9461\ \mathrm{g}$; $\Rightarrow n_1 = m_1 / M_1 = 1{,}10812\ \mathrm{mol}$;
$K_{G\,1} = 1.859\ \mathrm{K/mol}$;

$$n'_2 = \frac{n_1}{\frac{K_{G\,1} \cdot 1000\text{ g}}{\Delta T_G \cdot M_1} - 1} = 0.00778\text{ mol}$$

⇒ Number of dissolved particles: $N_2 = N_A \cdot n'_2 = 4.68 \cdot 10^{21}$.

Degree of Dissociation

$m_2 = 0.5420\text{ g}$; $M_2 = M_{KNO_3} = 101.1\text{ g/mol}$; ⇒ $n_2 = m_2 / M_2 = 0.005361\text{ mol}$;
$n'_2 = 0.00778\text{ mol}$; (see above)
$z = 2$ (because two ions are created from one KNO_3-molecule)
$\alpha = \frac{(n'_2 / n_2) - 1}{z - 1} = 0.450$.

Questions

What do you understand by an ideal solution?

A solution is called a diluted solution if the share of dissolved molecules is so small, that they nearly never meet each other and cannot interact with each other or disturb each other's interaction with the solvent. That's why the reciprocal action between the dissolved molecules and the rest of the solution isn't influenced by other dissolved molecules. By definition, this is the case if the share of the dissolved molecules is below one percent.
The solution is called ideal, if there are so few dissolved molecules, that there is absolute no influence as described above.

Why electrolytes aren't ideal solutions even in case of a high level of attenuation?

If electrolytes are dissolved, ions are created. The Coulomb forces between the ions cannot be ignored no matter how high the degree of attenuation is.

Which units are used in common for concentrations?

- **fraction of moles („Molenbruch“):** ratio of the quantity of the dissolved substance to the overall quantity of the substance
- **molality („Molalität“):** quantity of the dissolved substance per kg of the solvent
- **molarity („Molarität“):** quantity of the dissolved substance per liter of the solution

How is dissociation created ?

Dissociation is the process of polar solvents being arranged spherically around the ions, which has the effect of the ions being separated from each other, the ion grid disappears.

What do you understand by the degree of dissociation? How can it be determined?

The degree of dissociation is the ratio between the number of dissociated molecules and the number of all molecules. It can be determined by meassuring the electrical resistance of the solution or (Raoult's law) by the decrease (increase) of the freezing point (boiling point) (and other methods that are based on that, for example the change of the osmotic pressure).

Why is the vaporizing pressure of a solution of salt smaller than the vaporizing pressure of the solvent alone?

The vaporizing pressure of a solution is the ratio of the sum of the partial pressures of each substance to the fraction of moles. Because the vaporizing pressure of salts is approximately zero, the vaporizing pressure of the solution decreases by adding a salt.

How you can see from equation 4, that the melting pressure curve is steep?

The difference of the volumes $V_{liquid} - V_{solid}$ (molarity volume of the solvent in a liquid respectively solid state) is very small, therefore the curve of the melting pressure graph dP/dT is steep.

Explain the way how a freezing bath works. Why does the ice-water-mix cool down, if salt is mixed in? Is it possible to use another salt?

When extracting ions out of the crystal grid of the salt, dissociation energy is necessary (against the Coulomb force that attracts the ions to the grid). This energy is freed by the arrangement of polar solvent molecules around the produced ions (solvation energy; because of the Coulomb forces that attracts polar molecules (like water) to the charged ions). The difference of the disscociation energy and the solvation energy is the “solution warmth”. Depending on which one is higher, the “solution warmth” is endotherm or exotherm. By adding salt to the water endotherm “solution warmth” is freed and the solution cools down. Other salts with an equivalent endotherm “solution warmth” can be used in our experiment.

Why is the change of the electrical resistance with temperature of semiconductors higher than that of metals?

This behaviour can be explained with the band model. The conduction band of metals contains always many electrons (at any temperature; enough for big currents). This is the reason for the small electrical resistance. The resistance rises with rising temperatures because of the increased movement („Braunsche Bewegung“) of the particles (atoms/molecules) which disturbs the flow of the electrons.
The conduction band of semiconductors is empty at a temperature of 0 K. Energy is necessary to put electrons into the conduction band; this energy is provided by the thermic energy (which is Maxwell-distributed, so at almost any temperatures (except 0 K) electrons are in the conduction band – this is the reason why the resistance is also at low temperatures not infinite). With increasing temperature, the conduction band is filled up with more and more electrons, this decreases the resistance. But still, this limits the current; this effect is much bigger than the disturbance by the particles' movements.

What is meant by "negative temperature coefficient of the thermistor"?

Negative temperature coefficient means, that the electrical resistance of the thermistor decreases when temperature increases (as it is typical for semiconductors).