Physical Chemistry

Electrochemistry

Conductivity and ions

LD Chemistry Leaflets

C4.4.1.8

Conductivity of melts

Time required: 30 – 40 min

Aims of the experiment

- To measure electrical conductivity in liquids.
- To understand a melt as a liquid.
- To measure conductivity in a melt.
- Mole ratio and eutectics.

Principles

Electrical conductivity is a derived measurement parameter and a property of a substance. It is not just metals that conduct electrical current; so do solutions and melts of some substances. In metals, charge transport takes place through electrons that move through the metal lattice. In solutions, cations and anions transport the charges. Salts also consist of ions. The ions in a melt are no longer rigidly arranged at the lattice sites. They can move and transport charges. Therefore, salt melts are also conductive.

Because pure salts have a high melting point (NaCl: 800°C), in the experiment a mixture of two salts is used; in this case it is LiCl and KCl. At the so-called eutectic point (the eutectic point describes a phase equilibrium between the melt and the solid), a mixture at a specific mole ratio (the mole ratio is the ratio of the molarity of two substances) has its lowest melting point. The eutectic point is determined through experimentation. The eutectic point in the system LiCl/KCl is indicated as follows.

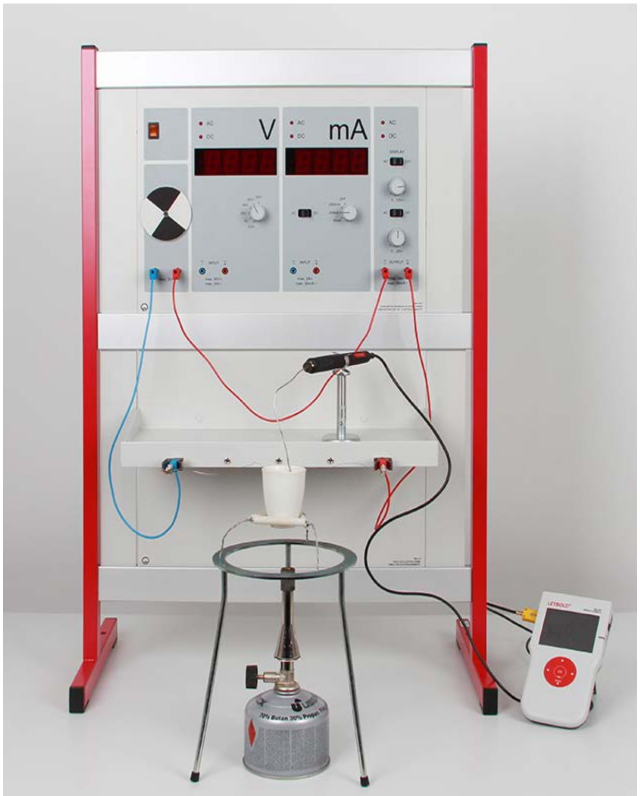

Fig. 1: Set-up of the experiment and materials.

55.7 mol% LiCl

& → T_E = <u>355 °C</u>

44.3 mol% KCl

From the eutectic point onward, a salt mixture is conducting because there are enough sufficiently mobile ions present. In the process, the conductivity increases as the temperature increases. Beginning at a specific temperature, the conductivity begins to approach a point of saturation since the probability of collision with adjacent particles continues to increase. The conductivity *G* can be calculated using the measured current *I* and voltage U.

$$G = \frac{I}{U}$$

In this experiment, the conductivity of the salt mixture KCl/LiCl will be investigated. The measurement will be carried out while taking notes of the temperature.

Risk assessment

CAUTION! To protect against any hot salt spraying, wear safety goggles and a lab coat! Do not touch the two wires (short circuit!). The wires must not touch one another.

Lithium chloride, anhydrous	
 **Signal word: Caution**	**Hazard warnings** H302 Health hazard if swallowed. H290 Can be corrosive to metals. H315 Causes skin irritation. H319 Causes serious eye irritation. **Safety information** P302+352 On contact with the skin, wash with plenty of water and soap. P305+P351+P338 IF IN EYES: Rinse carefully with water for several minutes. Remove contact lenses if present and if possible to do so. Continue rinsing.

AA-2018-07

Equipment and chemicals

1 Electrochemistry demonstration unit, CPS.....664 4071
1 Panel frame C50, two-level, for CPS 666 425
1 Electrochemistry accessories set...................664 401
1 Electrochemistry table, CPS 666 472
2 Clip plugs, small, set of 2 ....590 02ET2
1 Holder, magnetic, size 2, 11-14 mm 666 4662
3 Connecting leads .... from 664 401
1 Spatula, double ended 604 5663
1 Crucible porcelain 608 231
1 Cartridge burner...666 714
1 Wire triangle, with clay sleeves 666 689
1 Tripod...666 683
1 Temperature sensor................................ e.g. 529 676
1 Mobile CASSY 2 ....524 005
1 Scales ADACB1001
1 Copper wire (2 x 10cm)........................... from 664 401
1 Weighing paper, 100 sheets 661 044
1 Lithium chloride, anhydrous, 25 g 673 0500
1 Potassium chloride, 100 g.............................672 5200

Set-up and preparation of the experiment

Preparation of the experiment

First, the salts are weighed on the weighing paper using the spatula.

The following is required:

1. 2.02 g LiCl (0.0476 mol) ≡ 55.7 mol%
2. 2.93 g KCl (0.0378 mol) ≡ 44.3 mol%

Place both salts in the crucible and mix well using the spatula.

Set-up of the experiment

The set-up of the experiment consists of a tripod with a clay triangle base, two copper electrodes (about 10 cm long copper wires cut to length), a high temperature sensor, a suitable burner, three connecting leads and the demonstration unit.

Place the crucible with the salt mixture in the clay triangle base. Position the burner under the crucible such that about 5 cm of space exists between the gas outlet from the burner and the bottom of the crucible.

Connect the pieces of copper wire to the demonstration unit using the connecting lead. Fasten these electrodes in the outer table sockets using the crocodile clips and spring clamps.

Fasten the temperature sensor using the magnetic holder on the table (see Fig. 1). Connect the temperature sensor to Mobile CASSY 2. Suspend the electrodes and sensor in the salt mixture.

Caution! The electrodes must not touch one another.

Position the electrode and temperature sensor leads away from the flame. Connect one output socket of each power supply (5) to a copper electrode using a gripping clamp. At the power supply, set the changeover switch (2) to the AC (alternating current) position, and do the same for the changeover switch on the measuring unit (8). Turn on the measurement display of the power supply (selector switch (6)) (see Fig. 2 and Fig. 3).

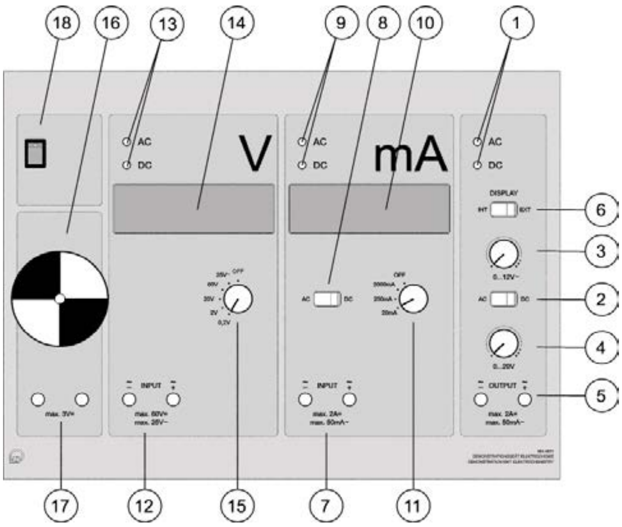

Fig. 2: Sketch of the demonstration unit.

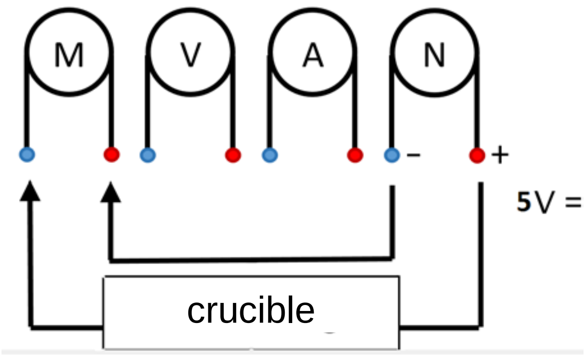

Fig. 3: Circuit for the experiment.

Performing the experiment

Insert the copper wires and temperature sensor into the salt mixture. The wires must be as far away as possible from one another. The temperature sensor can also be bent. Plug it into Mobile CASSY 2 in order to track the temperature. Turn on the demonstration unit. Apply a voltage of 5 V at the control dial. Now ignite the burner and heat the substance in the crucible using a blue flame (open the oxygen feed line slowly). Watch the temperature increase. Record temperature and current in a table.

Observation

It does not take long for the melt to start turning pink. A current of greater than zero is also quickly registered, even though the salt is still much like a solid (eutectic point). As the temperature increases, the salt mixture also visually appears to be liquid. The conductivity increases with temperature. At very high temperatures, a light “boiling” can also be heard. The cooling process is relatively quick. After cooling, the salt mixture still appears pale pink and not colourless as it was the case before the experiment.

It can be seen that the mixture converts to the liquid phase starting at about 365 °C. The salt melt appears pale pink. There remains a slight colouration even after cooling. The higher the temperature, the more current is conducted through the melt (see Tab. 1).

Tab. 1: Conductivity is dependent on the temperature of a melt (temperature and current are measured, conductivity is calculated).

Temperature (°C)	Current (mA)	Conductivity (S)
695	40	0.08
660	30	0.06
640	28	0.056
586	25	0.05
553	24	0.048
536	23.5	0.047
517	22.4	0.0448
501	22	0.044
479	20.5	0.041
465	19.8	0.0396
450	16	0.032
430	14	0.028
422	13.5	0.027
412	11.5	0.023
410	10	0.02
396	7.5	0.015
384	5.7	0.0114
378	4.5	0.009
367	2.9	0.0058
360	1.8	0.0036
351	1.0	0.00284

Evaluation

The conductivity *G* can be calculated as follows from the measured values for current and the applied voltage.

$$G = \frac{I}{U}$$

One conductivity is calculated exemplarily below.

$$G = \frac{16}{5} = 3.2\,mS \equiv 0.0032\,S$$

The values determined from the measurement can now be represented in a graph. The temperature is plotted on the Y-axis and the conductivity is plotted on the X-axis.

In the graph, it is clear that a noticeable saturation of conductivity occurs (see Fig. 4). The correlation for salt melts is therefore different to metals and conductors. Here, the conductivity or resistance is proportional to temperature.

Results

The exponential increase at the beginning can be explained by the free mobility of the ions. The ion lattice energy was overcome and the ions are therefore free in their direction and mobility. As the temperature increases, the probability of collision with a neighbouring ion also increases so that this disrupts electron transport.

The slight "boiling" can be described as an evaporation of crystal water.

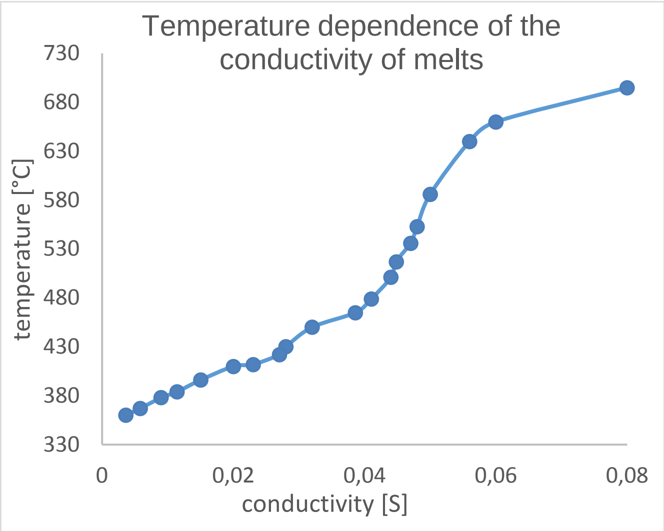

Fig. 4: Graphical plotting of temperature against conductivity.

Cleaning and disposal

Dispose of solid melts in inorganic solid waste after cooling, or re-use for another test. The crucible is rinsed with water and dried.

Application

Salts with low melting points (ionic liquids) which exist in liquid form at 50 – 80 °C are used frequently. They are used in the laboratory as a solvent replacement, wherein the chemical and physical properties of ionic liquids are very different.