The temperature dependence of conductivity with Cobra4 (Item No.: P3060560)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Chemistry	University	Physical Chemistry	Electro Chemistry	The temperature dependence of conductivity with Cobra4

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	1 Hour	2 Hours	2 Students

Additional Requirements:

- Precision balance, 620 g / 0.001 g
- PC with USB interface, Windows XP or higher

Experiment Variations:

Keywords:

Electrolytic resistance, conductance, specific and molar conductivity, ion mobility, equivalent conductance at infinite dilution, Kohlrausch's law, Ostwald's law of dilution, transference numbers, viscosity

Overview

Short description

Principle

The electrical conductivity of an electrolytic solution is dependent not only upon the type and concentration of the electrolytes, but also other state values. Thus, an increase in conductivity is generally observed with an increase in temperature. This is fundamentally due to the exponential decrease of the

solutions’s viscosity. In aqueous solutions a limit is reached at approximately 90 °C. Above this temperature the conductivity again decreases.

Fig. 1: Experimental set-up.

Safety instructions

When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing. Please refer to the appendix for detailed safety instructions.

Safety instructions

 

When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing.

Equipment

Position No.	Material	Order No.	Quantity
1	Magnetic stirrer with heater MRHei-Tec	35752-93	1
2	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	1
3	Cobra4 Sensor-Unit Conductivity+	12632-00	1
4	Conductivity temperature probe Pt1000	13701-01	1
5	Magnetic stirring bar 15 mm, cylindrical	46299-01	1
6	Magnetic stirring bar 25 mm, oval	46300-01	1
7	Spring balance holder	03065-20	1
8	Support rod with hole, stainless steel, 10 cm	02036-01	1
9	Supp.rod,stainl.steel,75cm,M10thr.	02023-20	1
10	Right angle boss-head clamp	37697-00	3
11	Universal clamp	37715-00	2
12	Round flask, 100 ml, 3-n., 3 x GL25	35677-15	1
13	Condenser, Dimroth type GL25/12	35815-15	1
14	Cristallizing dish,boro3.3, 500ml	46244-00	1
15	Funnel, glass, top dia. 55 mm	34457-00	1
16	Wash bottle, plastic, 500 ml	33931-00	1
17	Beaker, high, BORO 3.3, 250 ml	46027-00	1
18	Glass rod, boro 3.3, l=300 mm, d=8 mm	40485-06	1
19	Spoon, special steel	33398-00	1
20	Rubber tubing, i.d. 6 mm	39282-00	3
21	Hose clamp for 5-12 mm diameter	40997-00	4
22	Sodium chloride, 500 g	30155-50	1
23	Standard solution 1413µS/cm(25°C), 460ml	47070-02	1
24	Water, distilled 5 l	31246-81	1
25	Rubber caps, pack of 20	02615-03	1
26	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	1
27	curricuLAB measureLAB	14580-61	1
28	USB charger for Cobra4 Mobile-Link 2 and Wireless/USB-Link	07932-99	1

Task

Determine the temperature dependence of the conductivity of a 10% sodium chloride solution from 20 °C to approximately 60 °C.

Set-up and procedure

- Prepare the sodium chloride solution required for the experiment as follows:
  1 % NaCl solution: Weigh 1 g of dried sodium chloride and 99 g of distilled water into a 250 ml beaker and stir until the salt is completely dissolved.
- Set up the experiment as shown in Fig. 1.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

- Connect the measuring probe to the Cobra4 Sensor-Unit Conductivity +.
- Combine the Cobra4 Sensor Unit Conductivity with the Cobra4 Wireless-Link.
- Start the PC and connect it with the Cobra4 Wireless/USB-Link with a USB socket or wireless connection.
- After the Cobra4 Wireless-Link has been switched on, the sensor is automatically recognized.
- Start the software "measureLAB" and boot the experiment “The temperature dependence of conductivity” (experiment > open experiment). The measurement parameters for this experiment are loaded now.

- **For calibration:** Pour some standard solution into a beaker and immerse the well-rinsed probe into the solution (Note: Both platinum electrodes of the probe have to be covered completely with the solution).
- Go to and then click on Sensors/channels and select "Conductivity σ". To perform 2-point calibration, click on Calibrate sensor.
- Enter the corrected value for the conductivity at a given temperature (cf. Fig. 2). You can find this value on the label of the standard solution (at 25 °C with $C = 1413\ \mu S/\mathrm{cm}$) Click the “Apply corrected value” button and repeat this step for the second point of calibration. Finish the calibration with “OK”.

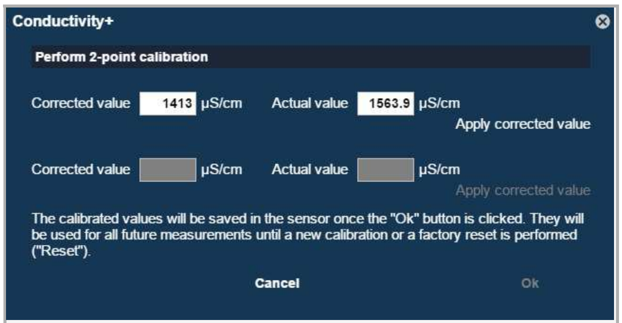

Fig. 2: Settings for the calibration mode of the sensor.

- **Procedure:** Half-fill the crystallizing dish with water and place it on the heating plate of the magnetic stirrer.
- Fill the three neck flask two thirds full with sodium chloride solution and attach it to the support rod of the magnetic stirrer so that it hangs half immersed in the water in the crystallizing dish.
- Place a magnetic stirrer bar in the three neck flask and another in the crystallizing dish.
- Mount the Dimroth condenser.
- Insert the conductivity probe in one of the side sleeves of the flask.
- Adjust the magnetic stirrer to a medium stirring speed, turn on the water for the condenser and switch on the heater.
- Start the measurement with .
- When the temperature reaches 90 °C, stop the measurement by pressing .
- Save your project by clicking on the button in the top bar.

- Fig. 3 shows the graph as it is presented by the programme.

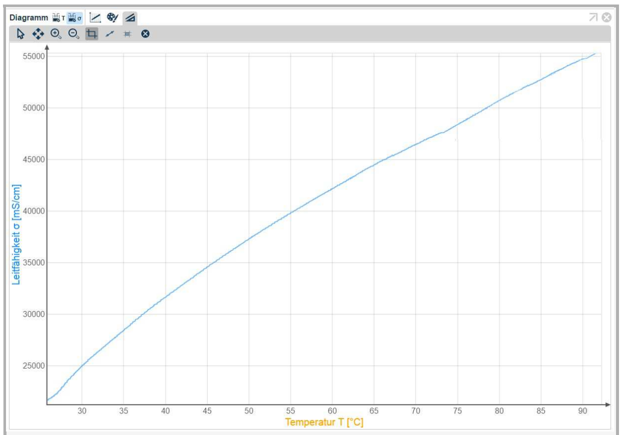

Fig. 3: Diagram of the conductivity of a sodium chloride solution as a function of the temperature.

Theory and evaluation

The conductivity of the aqueous sodium chloride solution increases linearly with temperature over the range from 20 °C to approximately 60 °C. The slope of the curve (approximately a straight line) shows the temperature dependence of the conductivity. This is given as the conductivity change per Kelvin or, more generally, in percent per Kelvin. The temperature coefficient α can be calculated from these values. This is defined as the change in conductivity $\Delta\kappa$ per 1 degree change in temperature, referred to the conductivity κ_R at the reference temperature T_R . It is therefore dependent on the reference temperature taken. At present, the standard reference temperature is $T_R = 298.15$.

$$\alpha_\vartheta = \frac{\Delta_K}{\Delta_\vartheta} \cdot \left(\frac{1}{K_R}\right) \cdot 100 \quad (1)$$

where

α_0 Temperature coefficient at a temperature of ϑ (in °C)

$\Delta_K / \Delta_\vartheta$ Change in conductivity Δ_K at a change of temperature of Δ_ϑ

K_R Conductivity at the reference temperature (25 °C)

m Slope of the regression line

Data and results

Slope: 0.4 mS cm^{-1} K^{-1}

Thus, a temperature coefficient of α_{25} = 1.9 % results from a conductivity of 21.1 mS cm^{-1} at 25 °C for the 1 % sodium chloride solution.

This experiment demonstrates the strong dependence of the conductivity on the temperature. Modern conductometers can compensate for the influence of temperature to a large extend through the use of combined conductivity/temperature probes. In simple cases this compensation is implemented with the

assistance of the temperature coefficient. The temperature coefficient is a substance-specific value and must be determined for each solution separately. It is dependent not only upon the dissolved substances, but also their concentration and the temperature range of the measurements.

Disposal

The diluted solution of sodium chloride can be disposed by rinsing into the drain.