

Determination of specific conductivity

Time required: 30 min

Aims of the experiment

- Investigation of the conductivity of tap water as an electrolyte
- Effect of electrode cross sectional area and electrode interspace on the conductivity of solutions.
- Conductivity as a substance-specific parameter
- Specific conductivity

Principles

The conductivity of a solution depends on many factors. In addition to the properties of the electrolyte, also the measurement arrangement is relevant. Therefore, in this experiment, the change in conductivity as a function of the fill height of the electrolysis cell and the electrode interspace will be investigated.

In order to investigate the dependence of conductivity on the electrode interspace and the electrode cross sectional area, two measurement series will be recorded. While performing the conductivity measurements, it is important to note that chemical changes can occur in the electrolyte at the electrodes and these changes become noticeable in part as concentration changes and in part in the form of polarisation voltages. Therefore, direct current is not used here, which corresponds to electrolysis, but rather higher-frequency alternating current will be used which will suppress these chang-

es.

Now, both properties can be coupled, which permits derivation of the general equation for specific conductivity.

$$G = \kappa \cdot \frac{A}{d}$$

G: Conductance [S]

κ : spec. conductivity [S/cm]

A: Electrode cross sectional area [cm²]

d: Electrode interspace [cm]

Risk assessment

In using the Electrochemistry Demonstration Unit, only voltages can be used that are not dangerous to the touch. Therefore, it can be assumed not dangerous.

Equipment and chemicals

1	Electrochemistry demonstration unit	664 4071
1	Electrochemistry accessory set.....	664 401
1	Panel frame C50	666 425
1	Electrochemistry table, CPS	666 472
1	Electrolysis cell	from 664 401
2	Nickel electrodes.....	from 664 401
2	Connecting leads	from 664 401
1	Drip pan	from 664 401

Additionally:
Tap water

Set-up and preparation of the experiment

Set-up of the experiment

The test set-up is shown in Figure 1. Two half cell blocks are combined into one electrolysis cell. Place one nickel electrode in each of the two outermost grooves of the electrolysis pan. Then, place the prepared electrolysis cell with the drip pan onto the electrochemistry table.

Connect an output plug socket (5) from the power supply to each nickel electrode, respectively, using a clip terminal (see Fig. 2 and 3).

At the power supply, set the rocker switch (2) to the DC (direct current) position, and do the same for the rocker switch on the measuring unit (8). Turn on the measurement display of the power supply (selector switch (6) to the left).



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

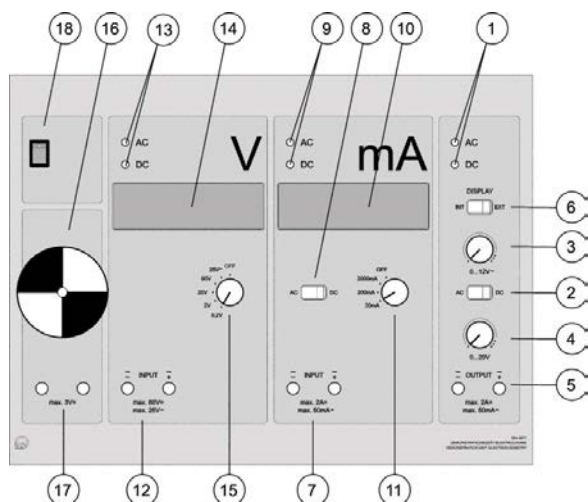


Fig. 2: Sketch of the demonstration unit.

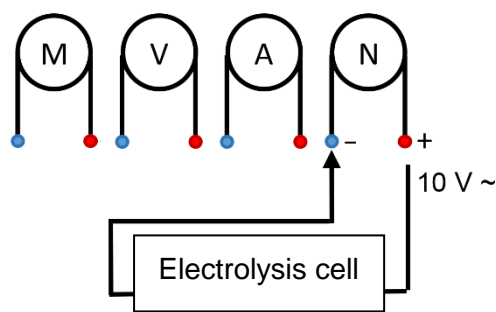


Fig. 3: Circuit for the experiment.

Performing the experiment

Influence of electrode cross sectional area on conductivity

In this experiment, the conductivity will be investigated as a function of electrode cross sectional area. In the process, the electrode cross sectional area will be varied by changing the fill height of the electrolyte.

The electrolyte used here will be tap water, from which the specific conductivity can be calculated; the specific conductivity, together with other parameters such as pH and water hardness, can provide conclusions about the types and amount of ions in the electrolyte. Alternatively, a very weak (approx. 0.02%) sodium chloride solution can be used as the electrolyte.

Set an alternative current (AC) value of 10 V using the control dial (3) at the power supply.

Take a reading of the current flow (display 10, which now of course is 0 mA) and tabulate it along with the fill height (0 cm).

Fill the tap water to the 1 cm mark in the electrolysis cell, readjust the voltage to 10 V if necessary and take a reading of the current again and record it together with the associated fill height.

Proceed in this manner until the 5 cm mark of the electrolysis cell is reached and record the associated value pairs.

Influence of electrode interspace on conductivity

In this part of the test, the separation of the electrodes from one another will be varied. Place two nickel electrodes into the outermost grooves of the electrolysis cell, which has been assembled as in the first test (see Fig. 2).

Place the electrolysis cell with the drip pan onto the demonstration unit tray and fill with tap water up to the 4 cm mark. For measurement of the current, apply an alternating current to the nickel electrodes at 10 V using the control dial. Readjust the voltage before each measurement if necessary (see Fig. 2).

The first measurement of current is done at an electrode interspace of 9 cm (electrodes in the outermost grooves). Then, for each subsequent measurement, alternately move the two electrodes inwards by one groove so that the electrode interspace is shortened by 1 cm each measurement.

Tabulate the measured current with the associated electrode interspace after setting a constant current. End the measurement at an electrode interspace of 1 cm and turn off the demonstration unit.

Observation

It can be seen that as the tap water fill height increases, i.e. as the electrode cross sectional area increases, the conductivity also increases (see Table 1). In the second part of the test, it can be seen that the electrical conductivity increases as the electrode interspace decreases, with the electrode cross sectional area remaining constant (see Table 2).

Evaluation

Influence of electrode cross sectional area on conductivity

The following table contains the value pairs determined for the dependence of current on electrode cross sectional area Φ . This is determined as

$$\Phi_{\text{Electrode}} = \text{fill height [cm]} \cdot \text{electrode width [4 cm]}$$

Tab. 1: Value pair for conductivity as a function of electrode cross sectional area.

No.	Fill height (cm)	Current (mA)	Effective electrode cross sectional area [cm ²]
1	0	0	0
2	1	2.7	4
3	2	5.2	8
4	3	7.9	12
5	4	10.4	16
6	5	12.5	20

From the measurement results, the general equation for electrical conductance or resistance can be derived. Also, the specific conductivity or specific resistance of an electrolyte can be determined from the converted equation.

The conductivity G and thus the current level I depend proportionally on the electrode cross sectional area A . Thus,

$$I \propto A \text{ or } G \propto A, \text{ respectively}$$

To investigate the dependency between the electrode cross sectional area and the current, the measured current is plotted against the respective effective electrode cross sectional area in a coordinate system (see Fig. 4).

From Figure 4 it can be seen that the current I – and thus the conductivity G – increases linearly with the electrode cross sectional area (wire cross sectional area) A . Thus, it can be stated that

$$I \sim A \text{ or } G \sim A, \text{ respectively}$$

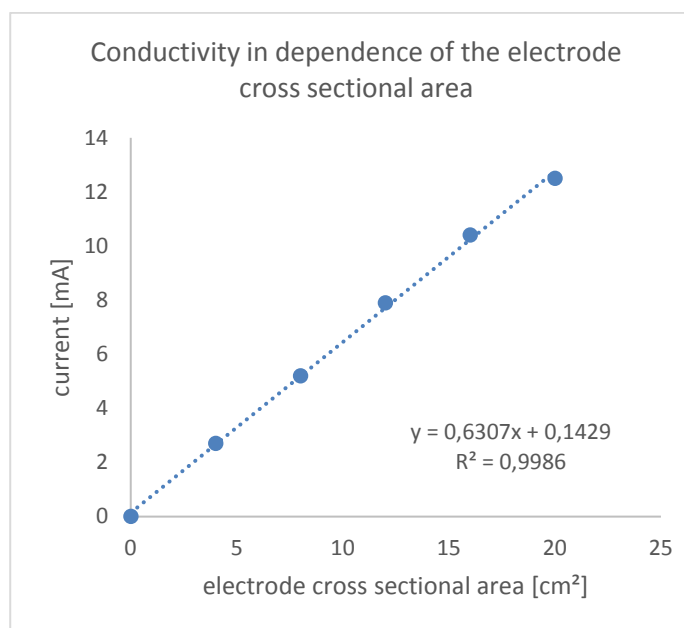


Fig. 4: Graphical representation of conductivity as a function of electrode cross sectional area.

Influence of electrode interspace on conductivity

Tab.2: Current as a function of fill height (electrode cross sectional area).

No.	Electrode interspace [cm]	Current (mA)
1	9	10.5
2	8	11.8
3	7	13.5
4	6	15.8
5	5	19.0
6	4	23.8
7	3	32.0
8	2	49.8
9	1	101.4

Entering the value pair into a coordinate system results in the following curve in Figure 5.

From this, it can be seen that the conductivity of an electrolyte – as well as a 1st order conductor – is inversely proportional to the electrode interspace: when the electrode interspace is increased, the current decreases - and vice versa.

For interspace d applies:

$$G \propto \frac{1}{d}$$

Combination of the test parts to determine the specific conductivity

If the relationship ($G \sim A$) determined in the above test section and the substance and concentration specific constants κ are combined, an overall relationship is obtained:

$$G = \kappa \cdot \frac{A}{d}$$

G = conductivity (conductance, S)
 κ = spec. conductivity (S/cm)
 A = electrode cross sectional area (cm²)
 d = electrode interspace (cm)

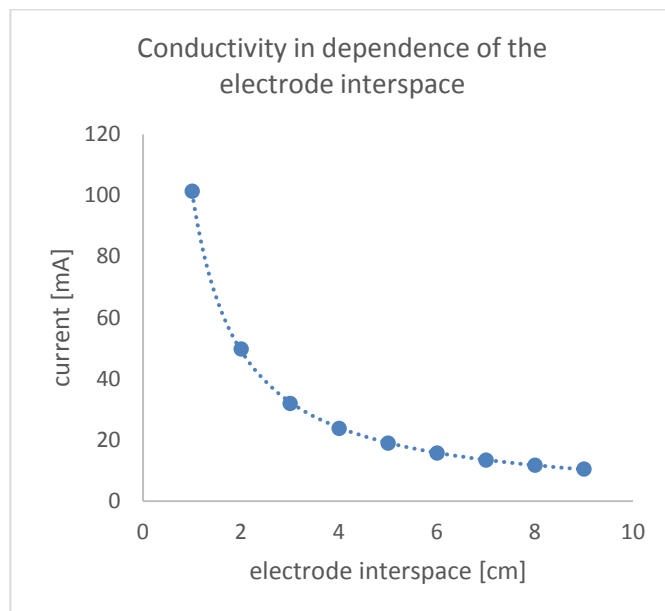


Fig. 5: Graphical representation of conductivity as a function of electrode interspace.

Therefore, with the known electrode cross sectional area A (here: 16 cm²) and interspace d , the specific conductivity κ of electrolytes can be calculated:

$$\kappa = \frac{G \cdot d}{A} \quad \text{in } \frac{\text{S}}{\text{cm}}$$

The value for G results from Ohm's law.

$$G = \frac{1}{R} = \frac{I}{U}$$

Since 10 V was selected as the voltage, G , and consequently κ , can be easily calculated. This is illustrated as an example for the first measurement. For the conductivity applies:

$$G = \frac{I}{U} = \frac{10.5 \text{ mA}}{10 \text{ V}} = 1.05 \text{ mS}$$

With the calculated conductivity, the specific conductivity κ can be determined via the electrode interspace d and cross sectional area A . The following applies

$$\kappa = \frac{G \cdot d}{A} = \frac{1.05 \text{ mS} \cdot 9 \text{ cm}}{16 \text{ cm}^2} = 0.59 \frac{\text{mS}}{\text{cm}}$$

For the remaining values, this calculation is carried out in the same way. This generates the following Table 3.

Tab.3: Determined and calculated values for the experiment.

	Electrode interspace d (cm)	Current I (mA)	Conductivity G (mS)	Spec. conductivity κ (mS/cm)
1	9	10.5	1.05	0.59
2	8	11.8	1.18	0.59
3	7	13.5	1.35	0.59
4	6	15.8	1.58	0.59

5	5	19.0	1.90	0.59
6	4	23.8	2.38	0.59
7	3	32.0	3.20	0.60
8	2	49.8	4.98	0.62
9	1	101.4	10.14	0.63
\bar{x} : 0.598				

The tap water used here therefore has a specific conductivity of about 0.60 mS/cm (= 600 μ S/cm). (EC guideline value for drinking water: max. 2790 μ S/cm: from Appendix 3 (to § 7 German TrinkwV 2001 + Amendment Nov. 2011)).

Result

The measured conductivity G becomes greater as the electrode interspace d becomes smaller and the greater the electrode cross sectional area A , i.e. the conductivity is proportional to A and inversely proportional to d . The constant of

proportionality is a specific characteristic of the electrolyte solution at a given concentration, temperature and pressure.

$$G \propto A, \quad G \propto \frac{1}{d}, \quad G \propto \frac{A}{d}, \quad \Rightarrow G = \kappa \cdot \frac{A}{d}$$

For more precise measurements of specific conductivity, an alternating current with a high frequency (e.g. 1000 Hz) should be used in addition to a precise, constant electrode interspace and cross sectional area (measurement cell) in order to completely exclude electrolytic processes, (see experiments on electrolysis in Chapter: C4.4.3).

Disposal

Empty the electrolysis cell and dry completely. Dry the electrodes well in order to prevent corrosion.