Effect of electrode gap on the Daniell cell

Time required: 20-30 min

Aims of the experiment

- To construct a galvanic element and to vary the electrode gap.
- Electrical resistance in solution.
- The force of the electric motor depends on the electrode gap.
- To minimise the cell resistance in order to get as much energy as possible.

Principles

In a galvanic element (or an electrochemical cell), chemical energy is converted into electrical energy. An electrochemical cell consists of two half cells. Each half cell contains an electrode that dips into an electrolyte solution (see Fig. 2). Thereby, electrons migrate from the anode to the cathode.

This process depends not only on the physiochemical properties of electrolyte solutions and electrode materials, but also on the electrode gap. The further away the electrodes are from one another, the larger the cell resistance according to *Ohm's law.* The electrical resistance prevents current flow in a galvanic cell. Therefore, one should try to minimise it as much as possible. Otherwise the released energy will be lost in the form of thermal energy.

Fig. 1: Experimental set-up and circuit.

For the cell resistance, the following applies

$$R = \frac{distance_{electrode}}{area_{electrode}} \cdot \frac{1}{conductivity}$$

As can be seen, the cell resistance increases linearly with the electrode gap. The electrode gap thus plays an important role in this process. What is responsible for the cell resistance? This can be explained as follows.

The conductivity of a solution is defined by the charged particles contained in it. It increases as the concentration of free ions in the solution increases. Different ions can transport charges at different rates. Therefore, the cell resistance (reciprocally of conductivity) depends on the molar conductivity of the different ions. The molar conductivity is a standard parameter and indicates the ability of 1 mole of a substance to transport the released electrons.

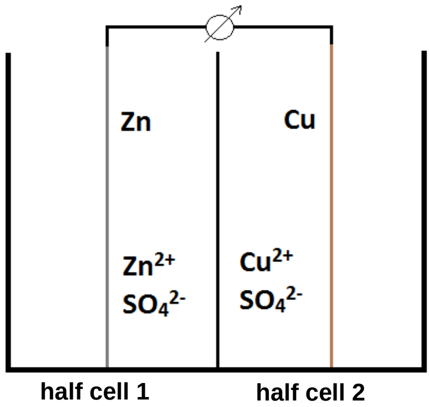

Fig. 2: Schematic of a Daniell cell

Figure 2 shows a schematic of the set-up of a *Daniell* cell. A zinc electrode is dipped into a zinc solution. A copper electrode is dipped into a copper solution. Both half cells are separated from one another, for example by a paper diaphragm. The electrodes are connected via a conductor and a measuring device or a load.

In this experiment, the electrode gap in the Daniell cell will be varied and the output of the Daniell cell measured.

AA-2018-07

Risk assessment

CAUTION: Zinc sulfate can damage eyes. Always wear a laboratory coat and goggles. Avoid skin contact.

Do not dispose of copper and zinc sulfate solutions in the sink.

Copper sulfate solution, 1 mol/l	
 **Signal word: Caution**	**Hazard warnings** H411 Toxic to aquatic life with long-lasting effects. **Safety information** P273 Avoid release into the environment.
Zinc sulfate solution, 1 mol/l	
  **Signal word: Hazard**	**Hazard warnings:** H318 Causes serious eye damage H411 Toxic to aquatic life with long-lasting effects. **Safety information:** P273 Avoid release into the environment. P280 Wear eye protection P305+351+338 IF THERE IS EYE CONTACT: Rinse continuously with water for several minutes. Remove contact lenses if present and if possible to do so. Continue rinsing. P313 Seek medical advice.

Equipment and chemicals

1 Electrochemistry demonstration unit, CPS.....664 4071
1 Panel frame C50, two-level, for CPS 666 425
1 Electrochemistry table, CPS 666 472
1 Electrochemistry accessories set..................664 401
1 Electrolysis cell ....from 664 401
1 Drip pan ....from 664 401
2 Paper diaphragm ....from 664 401
2 Crocodile clips...from 664 401
5 Connecting leads ....from 664 401
1 Zinc electrodes...from 664 401
1 Copper electrodes.......................................from 664 401
1 Measuring cylinder, 100 ml 665 754
2 Beaker, 150 ml...602 023
1 Beaker, 600 ml...664 132
1 Glass stirring rod.......................................665 212ET10
2 Graduated pipette, 10 ml 665 997
1 Pipetting ball 666 003
1 Water, pure, 1l 675 3400
1 Copper sulfate solution, approx. 1 mol/l.........672 9660
1 Zinc sulfate solution, 1 mol/l..........................675 5510
1 Sodium hydroxide solution, 0.1 mol/l 673 8411

Set-up and preparation of the experiment

Set-up of the experiment

Place the drip pan in the centre on the electrochemistry table. Fix the two half cells with the screws so that a gap about 0.5 cm wide remains open. Into this gap, place two paper diaphragms one atop the other and screw the two half-cells tight. The electrolysis cell is now sealed. Place a zinc and a copper electrode into the outermost groove, respectively (see Fig. 1).

Preparation of the experiment

Preparing the solutions: Solutions with a concentration of 0.1 mol/l are used. For each half cell, 80 ml of solution are required.

Place the pipetting ball onto the graduated pipette and draw 8 ml of copper sulfate (1 mol/l). Transfer this to a beaker. Now add 72 ml of water to this copper sulfate solution and stir with a glass rod. Label the beaker. Do the same to prepare the zinc sulfate solution, but use a second graduated pipette for this. Stir the solutions with a glass stirring rod prior to transferring them.

Circuit for the experiment: On the demonstration unit, switch the selector switch (6) to external power supply. Switch the changeover switch (8) on the display to DC power. Adjust the rotary switch (15) according to the measurement.

Connect the two electrodes of the cell to the input (12) of the voltmeter using two connecting leads with crocodile clips. Also connect the connections (7) on the amperemeter. Adjust the selector switch (11) (200 mA is sufficient). Connect the motor as shown in Figures 3 and 4 via jacks (17).

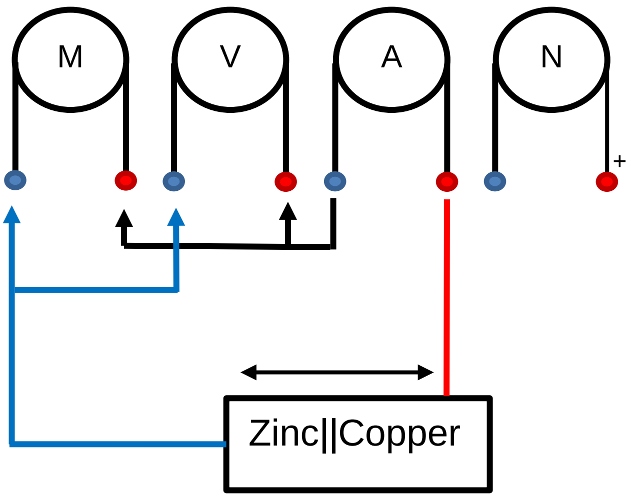

Fig. 3: Circuit for the experiment.

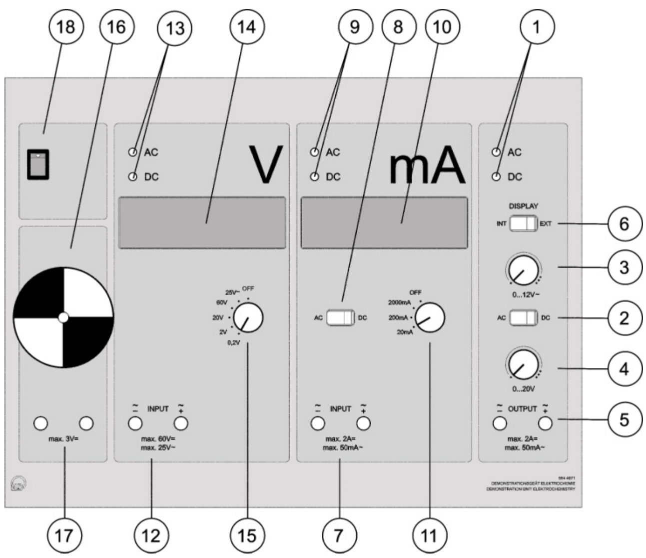

Fig. 4: Sketch of the demonstration unit.

Performing the experiment

Fill the zinc sulfate solution (0.01 mol/) into the zinc half cell. Fill the copper sulfate solution (0.1 mol/l) directly into the copper half cell. Observe the measurement displays and record the measurements. Now, connect the motor as shown in Figure 3 and record the measurements. Now move one of the two electrodes inward by one groove and record the values again. Alternatingly, move the two electrodes inward by one groove until the gap is 3 cm.

Empty the cells into a beaker (at least 500 ml) and rinse the electrolysis cell thoroughly.

Observation

The motor turns quicker as the electrode gap decreases.

A dark precipitate can be seen.

Evaluation

The following table contains the experimentally observed values.

The power *P* is equal to the product of current *I* and voltage *U*.

$$P = U \cdot I$$

Tab. 1: Current and voltage as a function of electrode gap, calculated power with electric motor connected; concentration 0.1 mol/l.

Gap [cm]	Voltage [mV]	Current [mA]	Power [mW]
9	392	6.80	2.67
8	432	7.03	3.04
7	472	7.32	3.46
6	517	7.75	4.01
5	567	8.25	4.65
4	621	8.75	5.40
3	688	9.55	6.57

Result

As can be seen, the potential difference and current increase as the electrode gap decreases. This also applies to the power. From the values given, the following graph (Fig. 5) can be composed.

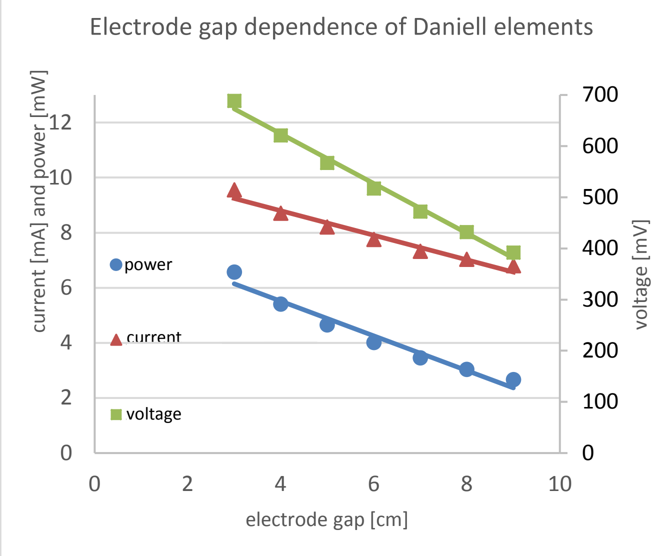

Fig. 5: Graphical evaluation of the gap measurements.

The power decreases linearly as the electrode gap increases. This can be explained by the fact that the internal resistance of the cell, and in particular that of the electrolytes, increases as the electrode gap increases.

Further remarks

The dark precipitate is finely distributed copper. Some Cu-II ions were able to diffuse through the diaphragm and were reduced to elemental copper in the zinc half cell. This can be verified by dissolving the black precipitate in concentrated nitric acid and adding this to an ammonia solution. Suddenly, a deep blue solution forms. This indicates that a stable copper tetraammine complex is present.

Reaction:

$Cu° + HNO_3 \rightarrow Cu^{II}(NO_3)_2 + 6\ NH_3 \rightarrow Cu^{II}(NH_3)_4 + 2\ NO_3^-$

Cleaning and disposal

Collect the solutions in a beaker, 600 ml, and add dilute NaOH solution. A black solid will precipitate, which seems insoluble. Filter it through a pleated filter and add more NaOH to the mother liquor. If no further black precipitate is seen, the mother liquor can be disposed of down the sink. Allow the filter to dry in the fume hood and then dispose of it in the inorganic solid waste.

$Zn^{2+}/Cu^{2+} + NaOH \rightarrow Zn(OH)_2 + Cu(OH)_2 + Na^+$