Effect of electrolyte concentration on the Daniell cell

Time required: 20-30 min

Aims of the experiment

- To construct a galvanic cell.
- To generate a measurable voltage using aqueous solutions.
- Effect of electrolyte concentration on the Daniell cell.
- To drive a motor using a Daniell cell.

Principles

The term galvanic cell describes a set-up for converting chemical 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. 1). The prime example of the galvanic cell is the Daniell cell. Here, a zinc electrode dips into a zinc sulfate solution and a copper electrode dips into a copper sulfate solution (see also Experiment C4.4.4.1). Figure 1 shows the schematic set-up of the Daniell cell.

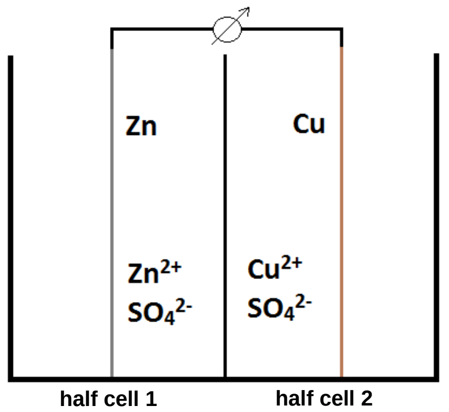

Fig. 1: Schematic of a Daniell cell. Both half cells must be separated by a paper diaphragm so that the solutions do not mix.

How do voltage and current arise in a galvanic cell? The potential difference, i.e. the measured voltage, of a cell depends on the electrode material. An increasingly different character of the two electrodes results in increasingly greater potential difference. The character of a substance is defined by its tendency to dissolve or precipitate, in other words how well it releases electrons to a reaction partner in a redox reaction. In the electrochemical series, substances are listed according to their character. At the top are the pure substances, and the substances become more and more impure going down the list.

The current of a galvanic cell, i.e. the amount of electrons that can migrate through the conductor, depends on the amount of the ions being supplied. The more ions being made available, the greater the current.

Fig. 2: Experimental set-up and circuit.

In this experiment, Daniell cells will be constructed that have different concentrations of metal salt solutions. The effect on the voltage and current of the Daniell cells will be investigated.

Risk assessment

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

Do not dispose of copper and zinc sulfate solutions down the laboratory drain.

AA-2018-07

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 IN CASE OF 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
4	Beaker, 150 ml	602 023
1	Beaker, 600 ml	664 11566
1	Glass stirring rod from a set of 10	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 of the electrochemistry table. Fix the two half cells with the screws so that a gap about 0.5 cm wide remains. In 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. 2).

Preparation of the experiment

Preparing the solutions: Solutions with concentrations of 0.1 mol/l and 0.01 mol/l are required. For each half cell, 80 ml of solution are required.

Place the pipetting ball onto the graduated pipette and initially draw 9 ml of copper sulfate (1 mol/l). Transfer this to a beaker. Now, add 81 ml of water to the copper sulfate solution and stir with a glass rod. Label the beaker. For the 0.01 mol/l solution, remove 8 ml of the prepared 0.1 mol/l solution using the graduated pipette and transfer it to a second beaker. Now add 72 ml of water to this and stir with a glass rod. Label the beaker.

Prepare the zinc sulfate solutions in the same manner. Use a clean graduated pipette here. Stir the solutions with a glass stirring rod prior to transferring them.

Circuit for the experiment: Switch the selector switch (6) on the demonstration unit to external power source (see Fig. 4). Switch the changeover switch (8) on the display to DC power. Adjust the rotating 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 via sockets (17) as shown in Figures 3 and 4.

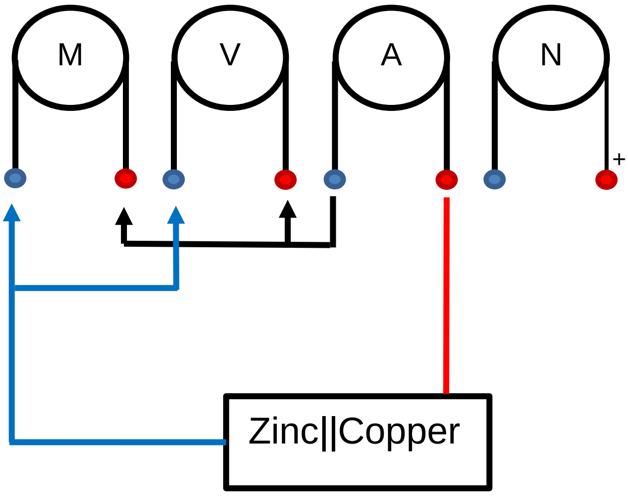

Fig. 3: Circuit for the experiment.

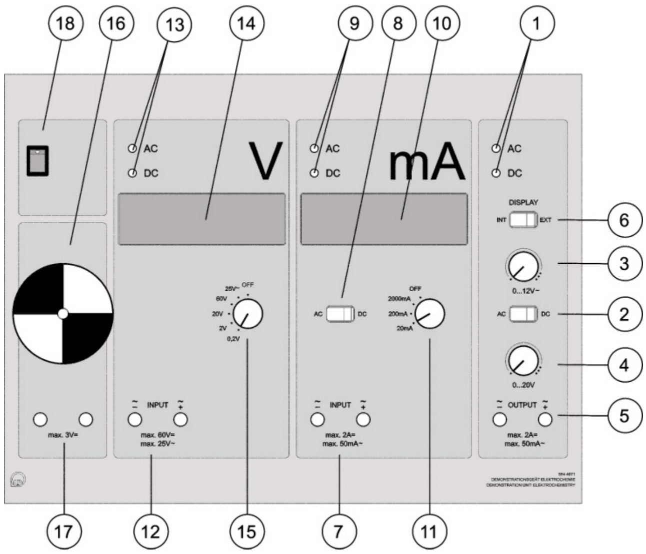

Fig. 4: Sketch of the demonstration unit.

Performing the experiment

Fill the zinc sulfate solution (0.01 mol/) into the zinc half cell. Fill the copper sulfate solution (0.01 mol/l) directly into the copper half cell. Observe the measurement displays and record the measurements. Now connect the motor and record the measurements. Also measure the short-circuit voltage and the short-circuit current. Unplug the motor when doing so. Connect the zinc to the negative sockets (12 and 7) and the copper to the positive sockets (12 and 7). Record the voltage and current.

Empty the cells into a beaker (at least 500 ml) and rinse the electrolysis cell thoroughly. If necessary, replace the diaphragms. Rinse the electrolysis cell with water. Then, carry out the same measurements using the concentrated (0.1 mol/l) electrolyte solutions.

Observation

The motor only rotates with the electrolytes at 0.1 mol/l concentration.

It can be assumed that a conversion of material is taking place in the solutions. In the zinc half cell, a dark precipitate can be seen (at both concentrations).

Evaluation

The following table contains the experimentally observed values.

Measured parameter	0.01 mol/l	0.1 mol/l
Voltage U	1001 mV	1090 mV
Motor	not running	running
Voltage under motor load	55 mV	380 mV
Current under motor load	1.7 mA	8.5 mA
Short circuit voltage	0.5 mV	26 mV
Short circuit current	1.66 mA	12.1 mA

Tab.1: Measured values and observation of the motor.

Results

Both cells exhibit the same voltages, but at different concentrations. This means that the potential difference does not depend on the concentration.

The current is different in the two cells. The current depends on the concentration of the electrolyte solution, i.e. it depends on the amount of electrons available. The motor only runs at high concentrations, since a certain amount of electrons must be available in order to achieve the required current.

The voltage drops when a connection is made to a load, in this case the motor. This process is typical for galvanic elements. In the non-operating state, the half cell has a voltage of 1.09 V and 1.01 V (a commercially available battery is about 1.5 – 1.8 V).

Further remarks

The black 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:

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

Cleaning and disposal

Collect the solutions in a beaker, 600 ml, and add dilute NaOH solution. A black solid will precipitate, which appears to be 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 laboratory drain. Allow the filter to dry in the fume hood and then dispose of it in the inorganic solid waste.

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