Physical Chemistry

Electrochemistry

Galvanic elements

LD Chemistry Leaflets

C4.4.4.1a

The Daniell cell

Set-up with the electrochemistry demo unit

Time required: 20 min

Aims of the experiment

- To construct a galvanic element.
- To understand galvanic elements and especially the *Daniell* cell as an energy converter.
- To generate a measurable voltage using aqueous solutions.
- Redox reaction and electrochemical potential series.

Principles

A *Daniell cell* describes what has historically been called a galvanic cell. A galvanic cell describes a device that allows to acquire electrical energy from chemical energy. In the process, redox reactions, i.e. reactions involving electron transfer, are used. Reduction and oxidation of the redox reaction are spatially separated. A galvanic cell is made up of two half cells. In the process, each half cell consists of an electrode and an electrolytic solution.

Fig.**1**: Experimental set-up and circuit.

The *Daniell cell* consists of a zinc half cell and a copper half cell. The two half cells are separated from each other spatially so that they are electrically conducting by an electron conductor and that they are ionically conducting by way of a diaphragm or ion bridge. The diaphragm or the ion bridge prevent diffusion of the electrolyte solution but does not prevent ion transfer. The electrolyte solution consists of zinc sulfate for the zinc half cell and analogously copper sulfate for the copper half cell (see Fig. 2). It was named after *John Frederic Daniell* and was developed in 1836.

The voltage or potential difference of a galvanic element is defined by the different electrodes. Different metals have different redox potentials and thereby different precipitation and solvation tendencies depending on the character of the metal (precious/non-precious). The redox reaction for the *Daniell cell* looks like this.

Oxidation: $Zn \rightarrow Zn^{2+} + 2e^-$

Reduction: $Cu^{2+} + 2e^- \rightarrow Cu$

Redox reaction: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

From the above equation, it can be seen that elemental zinc Zn^0 oxidises to Zn^{2+}, and Cu^{2+} reduces to elemental copper Cu^0. The electrons released by the zinc can either flow directly to the copper, thereby generating no current at all. If the two metals are separated, electrons can only flow through a conductor and a consumer load or measuring instrument. This is how energy can be acquired from a chemical reaction.

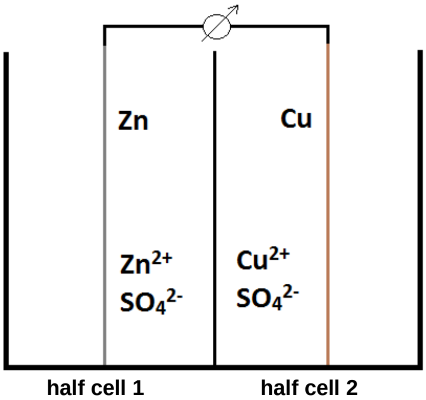

Fig. 2: Schematic of a Daniell cell

In this experiment, the *Daniell cell* will be constructed with an electrolyte concentration of 0.1 mol/l and it will be investigated. In order to visualise the potential difference, an electric motor is installed on the test apparatus. Also, current and voltage will be measured.

AA-2018-07

Risk assessment

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

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

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
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 (Peleus) 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 one electrode into each of the outermost grooves (see Fig. 2).

Preparation of the experiment

Preparing the solutions: Solutions with a concentration of 0.1mol/l are required. 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, 150 ml. Then add 72 ml of water. Do the same for the zinc sulfate solution. Prior to transferring the solutions, stir them with a glass stirring rod.

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 rotating switch (15) according to the measurement (see Fig. 3).

Connect the two electrodes of the cell to the input (12) of the voltmeter using two connecting leads with crocodile clips. Also connect with the sockets (7) of the amperemeter. Adjust the rotating switch (11) (200 mA is sufficient). Connect the motor as shown in Figure 4 via sockets (17).

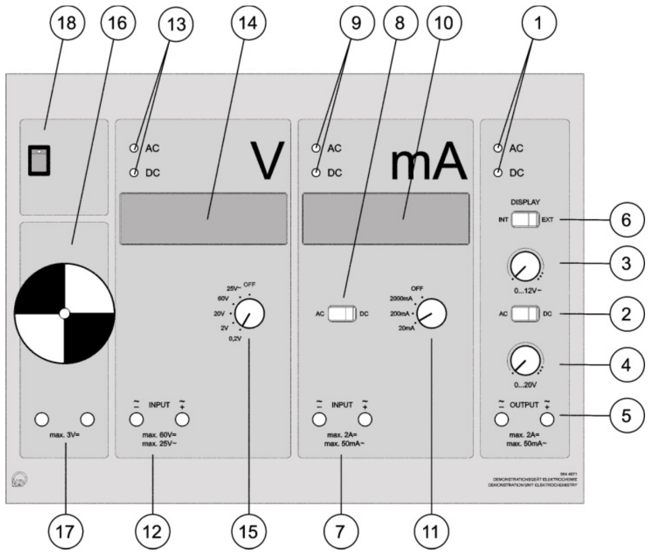

Fig. 3: Sketch of the demonstration unit.

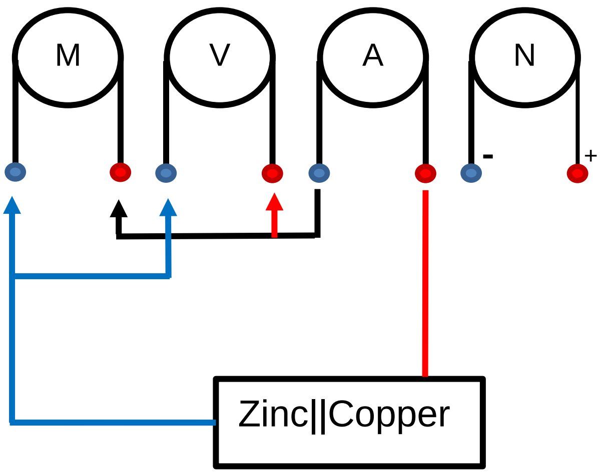

Fig. 4: Circuit for the experiment.

Performing the experiment

Fill the zinc sulfate solution into the zinc half cell. Fill the copper sulfate solution immediately into the copper half cell. Observe the 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 while doing so. Insert the zinc into the negative sockets (12) and (7) and the copper into the positive sockets (12) and (7). Record the voltage and current.

Observation

The motor turns as soon as it is connected to the Daniell cell.

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.

Evaluation

The following table contains the experimentally observed values.

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

Parameter	Daniell cell
Voltage U	1090 mV
Motor	Running
Voltage under motor load	380 mV
Current under motor load	8.5 mA
Short circuit voltage	26 mV
Short circuit current	12.1 mA

Results

In the non-operating state, a voltage of 1.09 V can be measured in the galvanic element. A commercially available battery is about 1.5 – 1.8 V.

The theoretically possible voltage can be calculated using the standard potential U^0_H from the electrochemical potential series. The following applies:

$U = U$ (Acceptor half cell) – U (Donator half cell)

$U = U^0_H$ (Cu2+/Cu) – U^0_H (Zn2+/Zn)

= 0.34 V – (- 0.76 V) = 1.10 V.

The measured value agrees well with the theoretical value.

As can be seen, the voltage decreases under load and especially when there is a short circuit. This is typical behaviour. If there is no load connected, or if the circuit is not closed, the electrical energy cannot flow and a maximum voltage builds up. As soon as the circuit is closed, electrical energy can flow and the voltage drops.

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:

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

Cleaning and disposal

Collect the solutions in a beaker (500 ml) and add diluted 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 drain. Allow the filter to dry in the fume hood and then dispose of it in the inorganic solid waste.

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