Physical Chemistry

Electrochemistry

Electrochemical potentials

LD Chemistry Leaflets

C4.4.4.6

Series and parallel connection of elements

Time required: 20-30 min

Aims of the experiment

- To construct a galvanic cell.
- To connect two galvanic cells together.
- To set up a series and parallel circuit.
- Effect of the circuit on the current and voltage.
- Batteries and accumulators in every day usage.

Principles

Every battery is a galvanic cell in which chemical energy is converted to 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 + 2).

Fig. 1: Experimental set-up and circuit.

As the reaction proceeds, one electrode decomposes, releasing electrons (anodic oxidation), whereas the other electrode can accept these electrons (cathodic reduction). When the reaction stops because one of the participants is depleted, the galvanic element is empty. For most applications, galvanic cells do not provide enough current *I* or voltage *U* and hence too little power *P*. The current *I* is determined by the electrolyte concentration. The voltage *U* is specified by the electrode material.

In order to increase the current or voltage, multiple galvanic cells are connected in series or in parallel. If galvanic cells are connected in series, higher voltages *U* are obtained since the individual voltages U_0 of the cells are added up (see *Kirchhoff's loop rule)*. On the other hand, if they are connected in parallel, the current *I* increases (see *Kirchhoff's junction rule*).

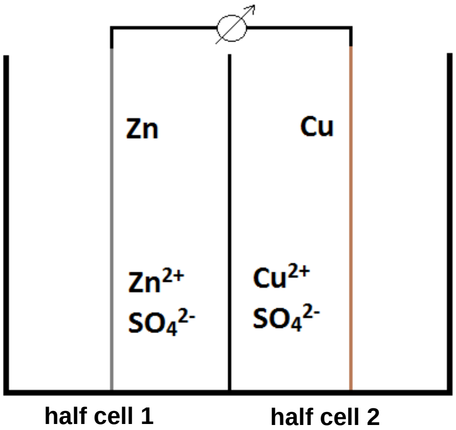

Fig. 2: Schematic of a Daniell cell

Figure 2 shows a schematic representation of a galvanic cell. The individual half cells are separated by a diaphragm. In this way, diffusion of the electrolytic solutions does not occur. The current flow, on the other hand, can pass through the diaphragm. The electrodes are connected through a load or a meter.

Batteries are connected galvanic cells. Common batteries include alkali-manganese cells (earlier zinc-carbon) that are connected in parallel. Such batteries are called primary cells since they can carry out only one discharge cycle.

Secondary cells are called accumulators. After one discharge cycle, the initial electrolytic state can be nearly restored so that the cell can be discharged again. The most commonly sold secondary cell is the lithium ion accumulator.

In this experiment, two galvanic cells will be connected in order to vary the current and the voltage.

AA-2018-07

Risk assessment

CAUTION: Zinc sulfate can damage the eyes. Always wear a laboratory 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
2 Electrolysis cell ....from 664 401
2 Drip pan ....from 664 401
4 Paper diaphragm ....from 664 401
4 Crocodile clips...from 664 401
7 Connecting leads ....from 664 401
2 Zinc electrodes...from 664 401
2 Copper electrodes..from 664 401
1 Measuring cylinder, 100 ml 665 754
4 Beaker, 150 ml..602 023
1 Beaker, 600 ml..664 132
2 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 on 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 in each of the outermost grooves. Proceed in the same way for the other two half cells (see Fig. 1).

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 150 ml beaker. Now add 72 ml of water to this copper sulfate solution and stir with a glass rod. Label the beaker. Repeat the process. Likewise, 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 (see Fig. 3).

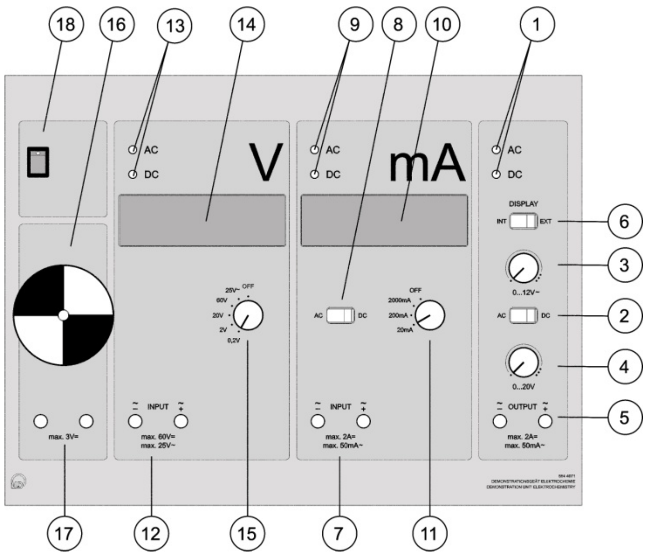

Fig. 3: Sketch of the demonstration unit.

Connect the two electrodes of the cell to the input (12) of the voltmeter using two connecting leads with crocodile clips. Also connect (7) with the amperemeter. Adjust the selector switch (11) (200 mA is sufficient). Connect the motor via sockets (17) as shown in Figures 3 and 4. For the series circuit, one cell is connected to the adjacent cell. Here, a copper electrode is connected to a zinc electrode (see Fig. 4a).

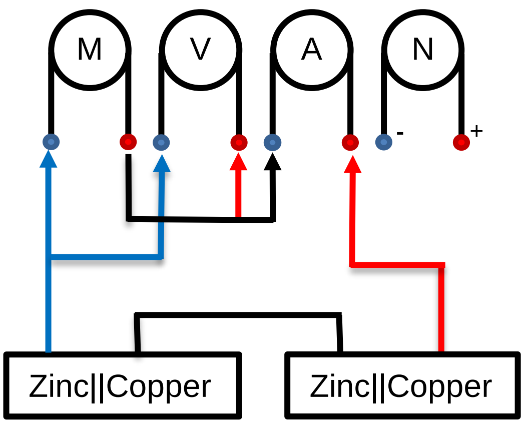

Fig. 4a: Series circuit of the experiment.

For a parallel circuit, the zinc electrode of a cell is connected to the zinc electrode of another cell and a copper electrode is connected to the other copper electrode (see Fig. 4b).

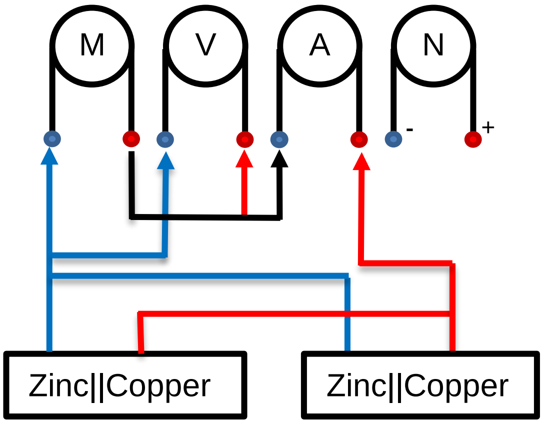

Fig. 4b: Parallel circuit of the experiment.

Performing the experiment

First, investigate the cells connected in series. Fill the zinc sulfate solution (0.01 mol/) into the zinc half cell. Fill the copper sulfate solution (0.1 mol/l) into the copper half cell, immediately. 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. 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.

Proceed in the same way with the parallel cell circuit. At the end of the measurement, empty the cells into a beaker (at least 500 ml) and rinse the electrolysis cell thoroughly.

Observation

The motor turns under both circuits. 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.

Measured parameter	Parallel	Series
Quiescent voltage U_0	1090 mV	2150 mV
Motor	Running	Running
Voltage under motor load	340 mV	300 mV
Current under motor load	12.5 mA	8.15 mA
Short circuit voltage	40 mV	20 mV
Short circuit current	28 mA	9.8 mA

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

Results

The motor runs in both circuits. In the series circuit, the quiescent voltage has doubled (see the *loop rule*).

It can also be seen that the current in the parallel circuit is greater (see current and motor load or short circuit current).

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. 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, 500 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 sink. Allow the filter to dry in the fume hood and then dispose of it in the inorganic solid waste.

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