

## Recording characteristic curves of a Daniell cell

with the electrochemistry demo unit

Time required: 30 min

### Aims of the experiment

- To construct a galvanic cell.
- To record a load characteristic curve, using a variable resistance.
- To calculate the performance characteristic curve from the load characteristic curve.

### Principles

In electrical engineering, there are at least two different kinds of voltage sources.

#### Ideal voltage sources

The ideal voltage source describes a voltage source in which the output voltage does not decrease regardless of how large the exiting current is. Theoretically, an infinitely high current could be achieved this way. The output voltage in ideal voltage sources is frequently called a constant voltage source. The ideal voltage source is only a model since the internal resistance is equal to zero in such sources.

#### Real voltage sources

The real voltage source describes a voltage source in which the output voltage decreases with increasing load current. The voltage loss arises from resistances and the design of the voltage source. Frequently, internal resistances are at work.

A galvanic cell is a real voltage source. The reason for this is the internal resistance of a galvanic cell as discussed in Experiment C4.4.4.5. This can be minimised by reducing the electrode gap, but cannot equal zero.

Load characteristic curves and power curves show characteristic properties for galvanic cells and other current-generating elements such as fuel cells or solar cells. A load characteristic curve or voltage characteristic curve describes the functional relationship between the voltage and the so-called load current. The power curve describes the power provided by a system upon withdrawal of an electric current.

In the experiment, load characteristic curves and power curves of a *Daniell* cell will be recorded.

#### 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.

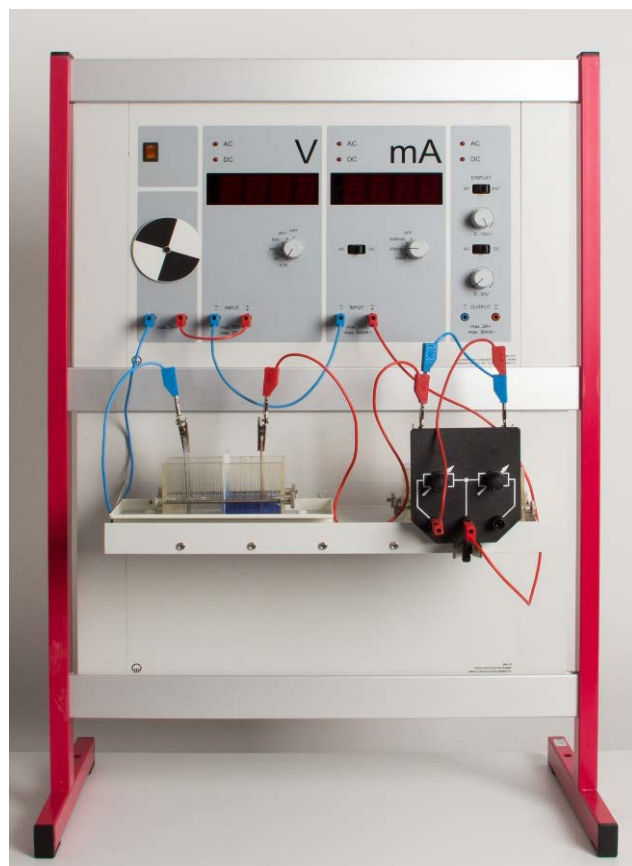


Fig. 1: Experimental set-up and circuit.

#### 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.

Copper sulfate solution, 1 mol/l	
	<b>Hazard warnings:</b> H411 Toxic to aquatic life with long-lasting effects.  <b>Safety information:</b> P273 Avoid release into the environment.
<b>Signal word:</b> <b>Caution</b>	

### 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	On-screen resistance module .....	458 120
1	Electrolysis cell .....	from 664 401
2	Drip pan .....	from 664 401
2	Paper diaphragm .....	from 664 401
4	Crocodile clips.....	from 664 401
6	Connecting leads .....	from 664 401
1	Zinc electrodes.....	from 664 401
1	Copper electrodes.....	from 664 401
1	Measuring cylinder, 100 ml .....	665 754
1	Beaker, 600 ml.....	664 132
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 cell with the screws so that a gap about 0.5 cm wide remains open. 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 3 cm apart (see Fig. 2).

### Preparation of the experiment

Solutions with a concentration of 1 mol/l are required. For each half cell, approx. 80 ml of solution are required.

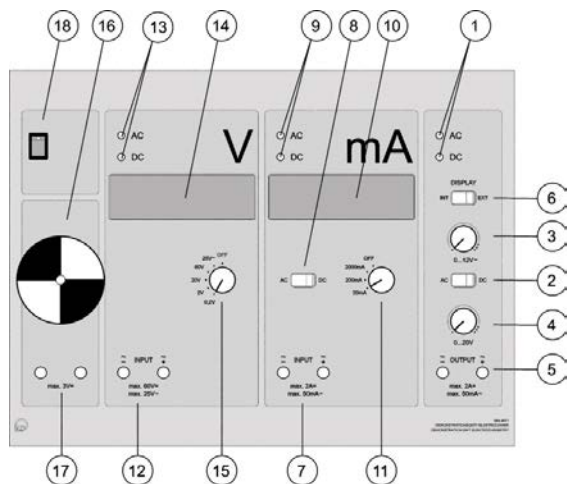


Fig. 3: Sketch of the demonstration unit.

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).

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 copper electrode to the load element (resistance module) as shown in Figure 3. Connect the load element to the amperemeter through connection (7) (see Fig. 3 and 4).

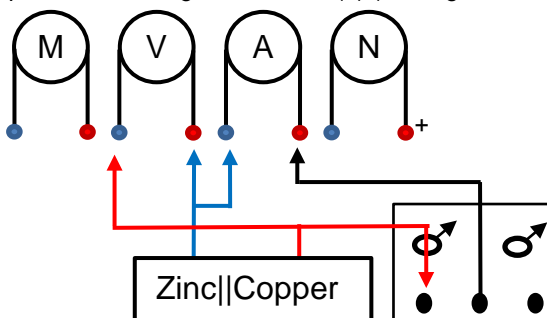


Fig. 4: Circuit for the experiment.

## Performing the experiment

Fill the zinc sulfate solution into the zinc half cell. Fill the copper sulfate solution directly into the copper half cell. Observe the measurement displays and record the measurements. Connect the load element only for the duration of the measurement period in order not to overload the galvanic cell.

First, record the voltage of the unloaded element. Then, connect the load element to the amperemeter and set both controllers (coarse and fine settings) to maximum resistance so that only minimal current flows. Record the values.

By changing the resistance (initially using the coarse controller, then with the fine controller), the current flow can be raised by 5 mA at a time and the voltage and current recorded. When the current can no longer be increased, end the measurement. Empty the cells into a beaker (at least 500 ml) and rinse the electrolysis cell thoroughly.

## Observation

As the load decreases, the current increases. In the zinc half cell, a dark precipitate can be seen.

## Evaluation

Table 1 contains the experimentally observed values.

The voltage values are entered into a coordinate system (see Fig. 5) as a function of the current. Also, the power  $P$  can be calculated using  $I$

$$P = U \cdot I$$

and likewise added to the graph (see Fig. 5).

**Tab. 1:** Observed and calculated values. Effective power  $P$  was calculated as shown below, 1 mol/l; electrode gap 3 cm.

No.	Voltage [mV]	Current (mA)	Power [mW]
1	1045	0.08	0.083
2	1003	10.1	10.1
3	981	15	14.7
4	953	20	19.1
5	925	25	23.1
6	896	30	26.9
7	865	35	30.3
8	833	40	33.3
9	802	45	36.1
10	777	50	38.9
11	744	55	40.9
12	717	60	43.0
13	691	65	44.9
14	666	70	46.6
15	639	75	47.9
16	587	85	49.9
17	563	90	50.7
18	538	95	51.1
<b>19</b>	<b>515</b>	<b>100</b>	<b>51.5</b>
20	489	105	51.3
21	466	110	51.3
22	439	115	50.5
23	415	120	49.8
24	389	125	48.6
25	366	130	47.6
26	341	135	46.0
27	316	140	44.2
28	291	145	42.2
29	266	150	39.9
30	241	155	37.4
31	213	160	34.1
32	195	165	32.2
33	164	170	27.9
34	145	175	25.4
35	122	180	21.9
36	93	185	17.2
37	70	190	13.3

## Results

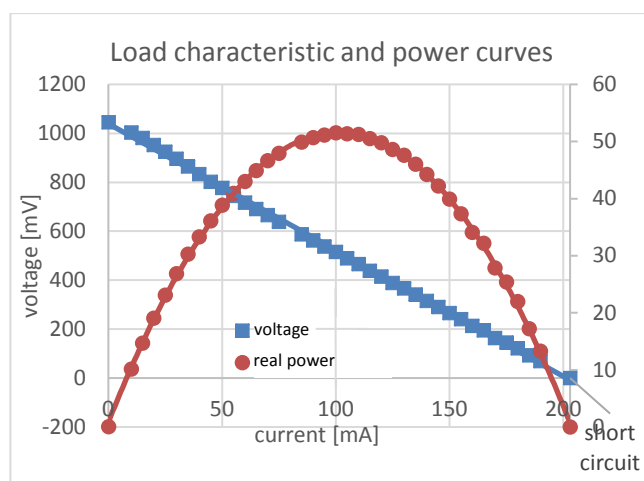
The voltage is linearly dependent on the current. The higher the current, the lower the voltage of the Daniell cell.

The power increases as the current increases until a maximum is reached at about 100 mA. This corresponds to an optimum working resistance according to *Ohm's law*.

$$R = \frac{U}{I} = \frac{0.515 \text{ V}}{0.1 \text{ A}} = 5.15 \Omega$$

If the electrode gap is increased, the value would also increase since the internal resistance of the cell increases. The power is at its highest when the internal resistance of the current source and the resistance of the load are about the same.

Moreover, the power drops since the voltage also decreases linearly. If the voltage drops to 0, this is equivalent to a short circuit. The functions were modified by a regression since no short circuit could be reached.

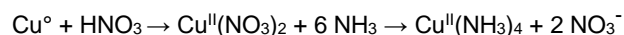


**Fig. 5:** Load characteristic curve and power curve of a *Daniell* cell.

## 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:*



## 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.

