

Nickel-Iron battery

[http://en.wikipedia.org/wiki/Nickel-iron\\_battery](http://en.wikipedia.org/wiki/Nickel-iron_battery)

<http://www.beutilityfree.com/nife.html>

**Datalogging and data analysis using the Program CHEMEX and the  
Analog-Digital-Converter CHEMBOX  
IBK electronic + informatic**

**Disclaimer: The experiment described below is not recommended to be performed on your own. If you attempt to reproduce this experiment, the author accepts no responsibility or liability for loss, damage or injury resulting from errors, omissions or the use or misuse of any information contained in this page. Any users of the procedure provided on this website assume all responsibility for the safe handling of hazardous chemicals.**

**German version**

**Chemicals** 20% potassium hydroxide solution  
:

**Apparatus and glass  
wares:**

600 mL beaker  
iron sheet metal 5 · 10 cm  
nickel plate 5 · 10 cm  
iron wire net  
nickel wire net  
DC voltage source  
ammeter  
voltmeter  
switch  
rheostat 100  $\Omega$  (variable  
resistor)  
path cords

clamps

### Hazards and safety precautions:



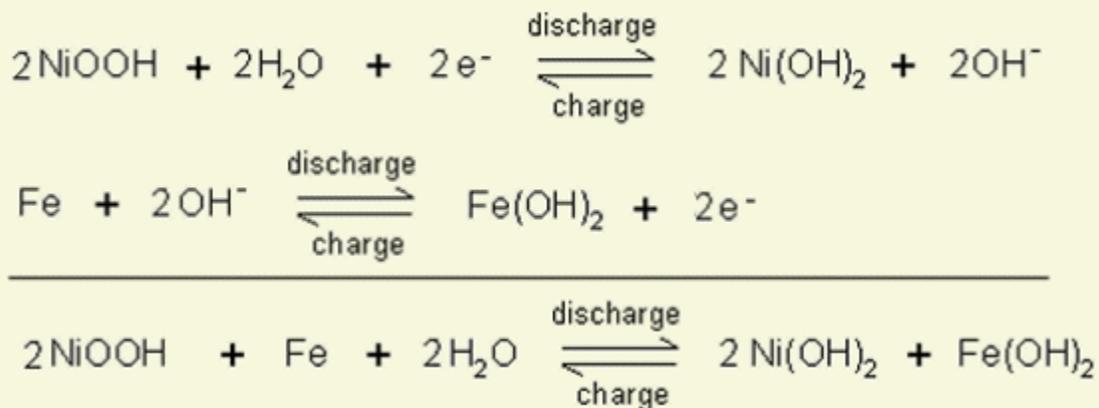
**Potassium hydroxide solution** is corrosive! Contact with skin can cause irritation or severe burns and scarring with greater exposures. Swallowing may cause severe burns of mouth, throat, and stomach.

**Safety glasses and protective gloves required.**

### Theoretical background:

A secondary cell devised by Thomas Edison (1847-1931) having a positive plate of nickel oxide and a negative plate of iron both immersed in an electrolyte of potassium hydroxide.

The reaction on discharge and charge is:

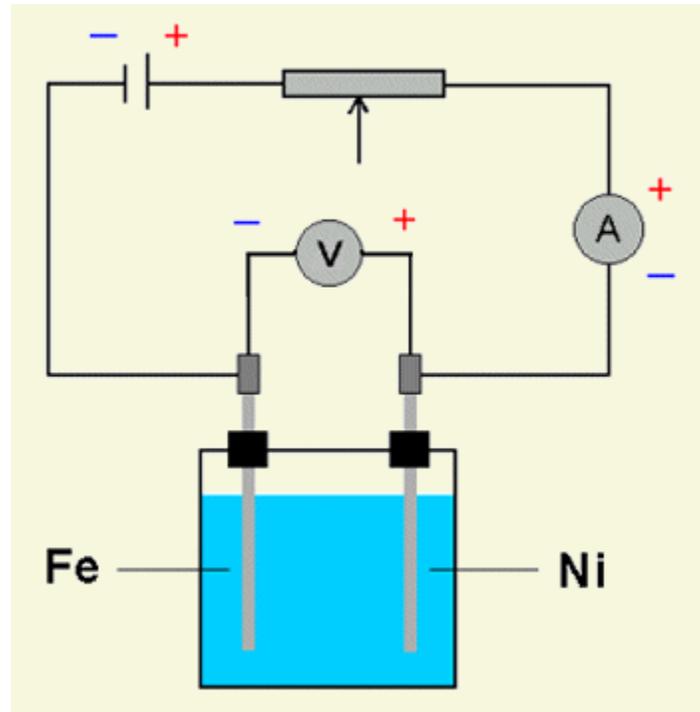


### Preparation:

The iron sheet metal is enclosed by an iron wire net, firmly fastened with wires to the iron plate. In the same manner a nickel plate is enclosed by a nickel wire net. The two electrodes are hung vertically into a beaker filled with 20% potassium hydroxide solution. The surface area of the electrodes immersed in the electrolyte is approx.  $75\text{ cm}^2$ . The ends of the wire net are wedged into slotted rubber plugs mounted on a stand. The metal plates allow accurate placement of the nets.

The iron net is connected to the negative terminal, the nickel net to the positive terminal of DC voltage source. The rheostat is adjusted in a manner that allows a current of 200 to

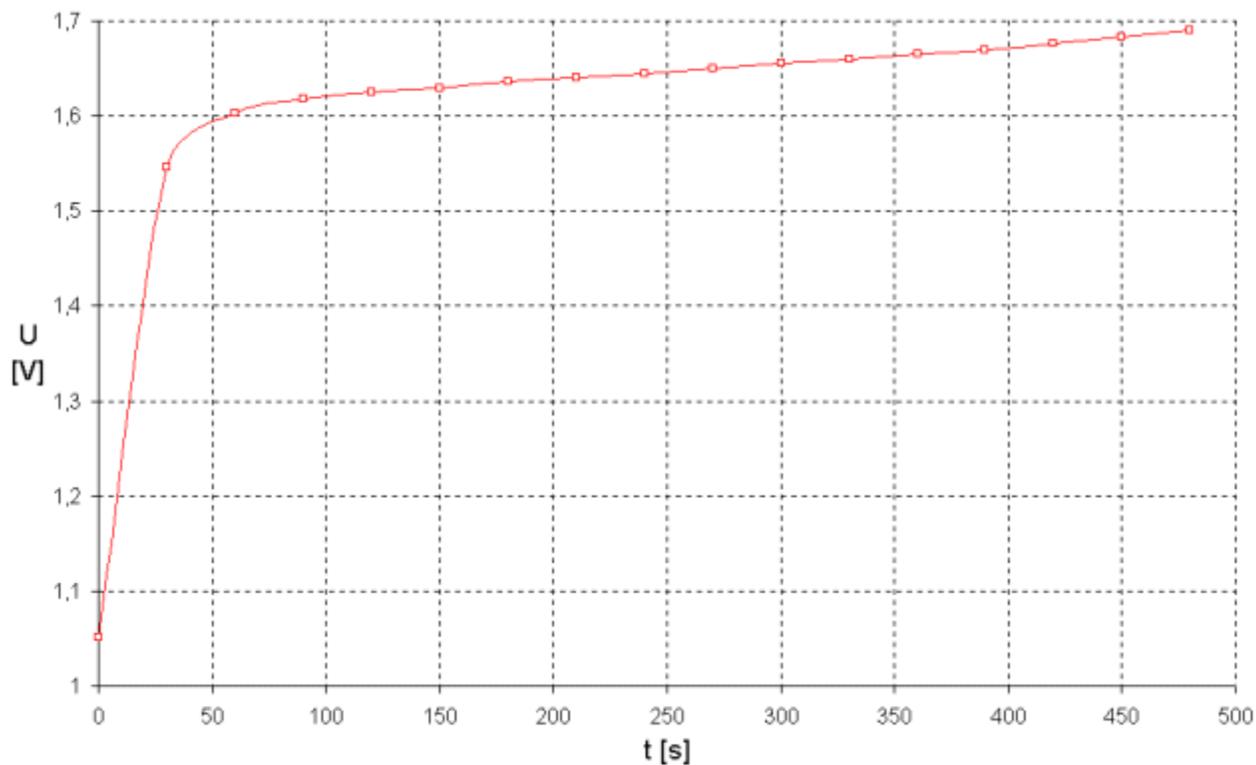
300 mA to flow (**Fig. 1**). The battery is charged for 30 minutes.



**Fig. 1: Charging of the cell**

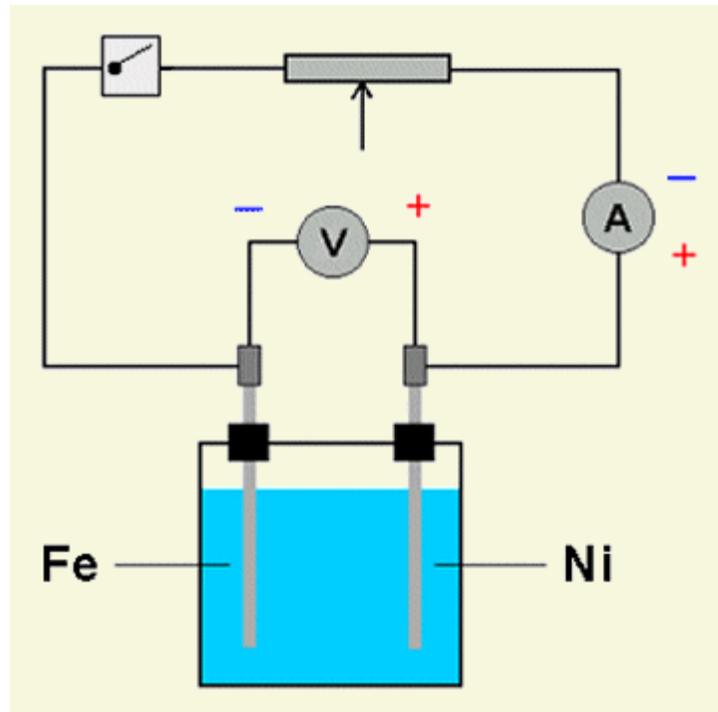
At the two electrodes a gassing occurs. The voltage of the cell decreases within a day below a value 0.5 V (**Fig. 3**).

Next day the cell is charged for 10 minutes (as above described). The voltage rises to 1.7 to 1.9 V.



**Fig. 2: Potential gradient while battery charging**  
(data logging with Cassy)

After power-off of the voltage source, one connects the nickel electrode via the ammeter, the rheostat and a switch to the iron electrode. The rheostat is adjusted in such a way, that a current of 20 mA flows (**Fig. 3**). The voltage decreases within of 3 minutes to 0.2 V. After interruption of the external electric circuit the voltage rises again slowly to 1 V.



**Fig. 3: Battery discharge**

### Experimental procedure:

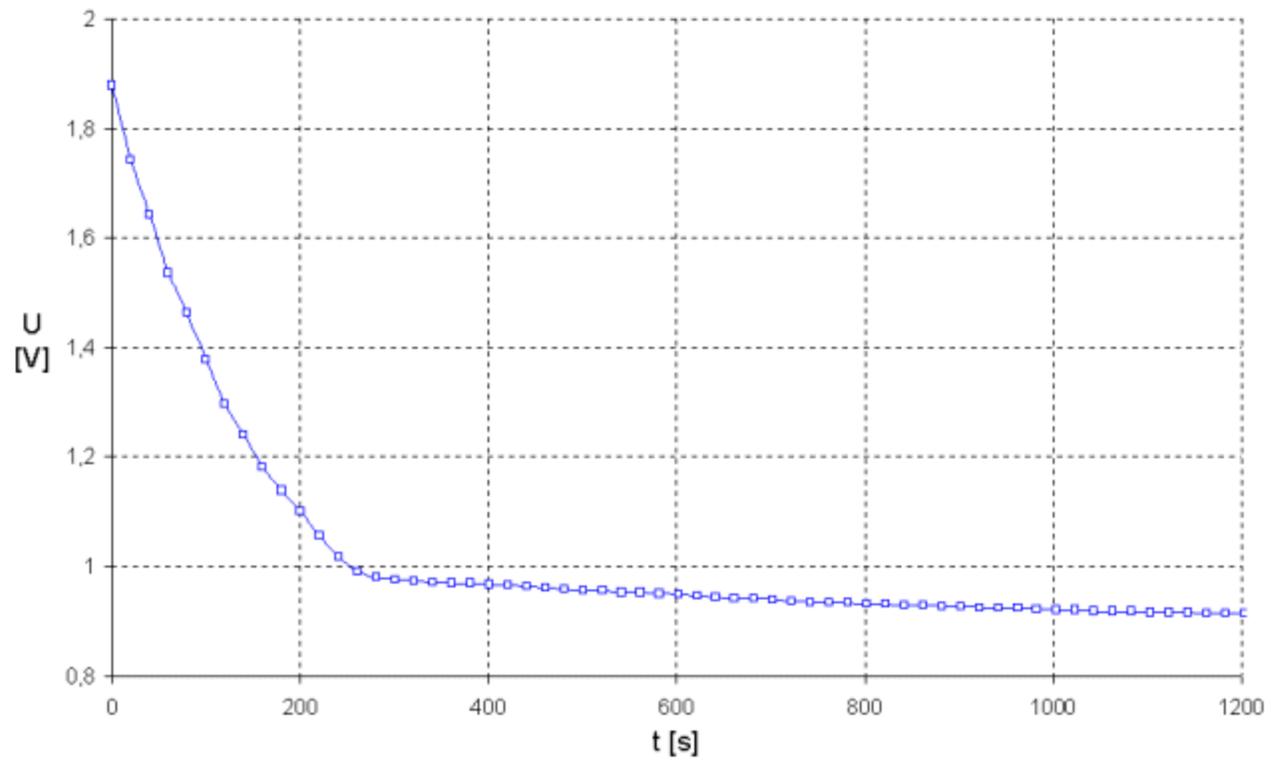
#### Matching of the program CHEMEX

The positive terminal of the voltage source is connected via the rheostat and the ammeter to the nickel electrode. The iron electrode is connected to the negative terminal. The voltmeter displays a voltage of 1.5 V. The voltage produced by the electrochemical cell is used for the calibration. The program CHEMEX is switched to 'Options / Calibration / Sensor1'. One sets the first point of reference on 0 V. Afterwards the voltmeter is replaced by the CHEMBOX: the Ni-electrode is connected to the positive terminal, the Fe-electrode to the negative terminal of the 'Input Sensor1' of the CHEMBOX. As a second point of reference is taken the voltage value of the cell. In order to check the matching of the program is switched to the analog / digital display for voltage 1. If the appropriate voltage value is not displayed, the calibration is to be repeated.

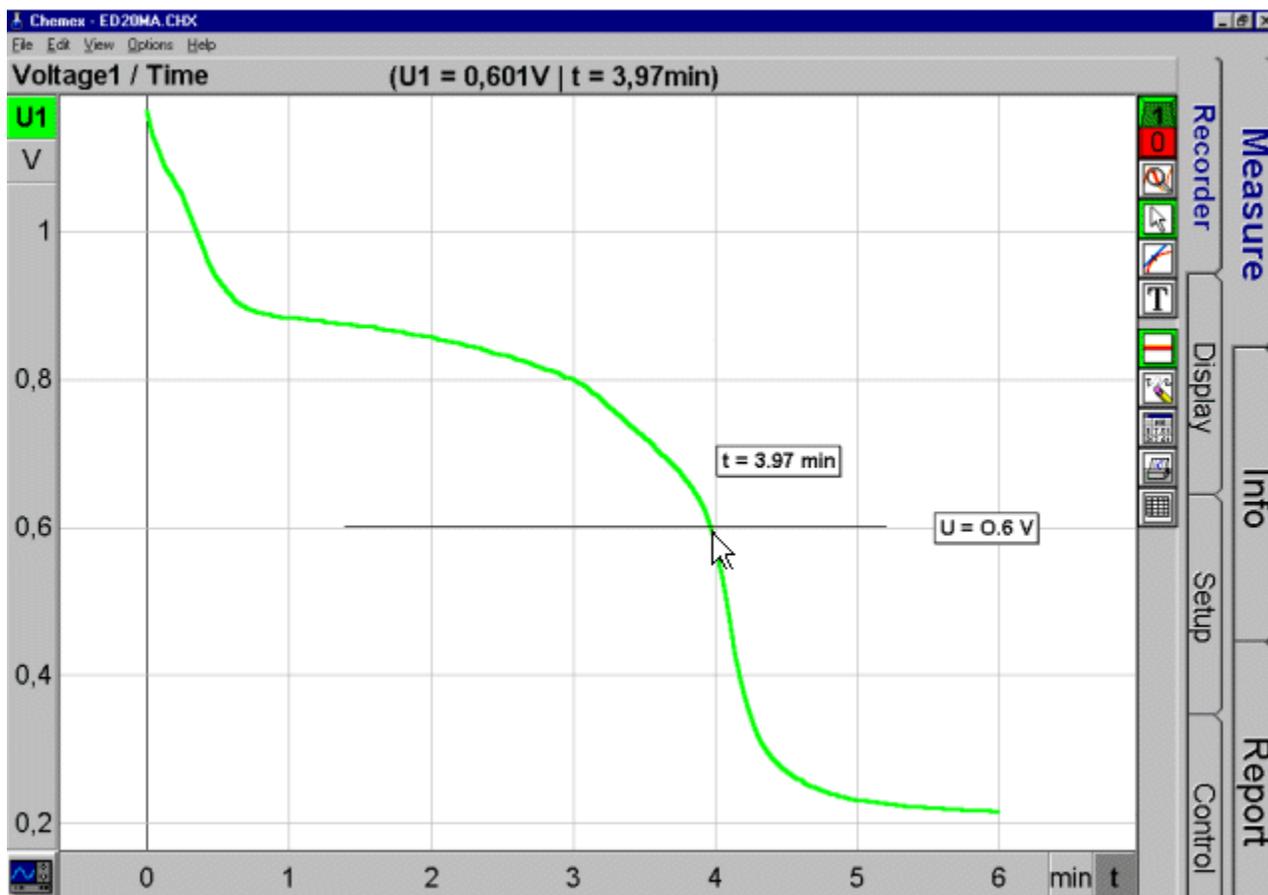
#### Measurements:

After the cell was charged with a current of 100 mA, it is discharged at 20 mA. Next the re-charged battery is discharged at 30 and 40 mA. The changes in voltage are recorded at a 2 second interval.

The Edison cell exhibits a high self discharge. The voltage decreases to 1.0 V within approx. 250 seconds. Then it levels off as time goes on. Therefore the measurements are started at the time where a voltage of approximately 1.2 V has been reached.



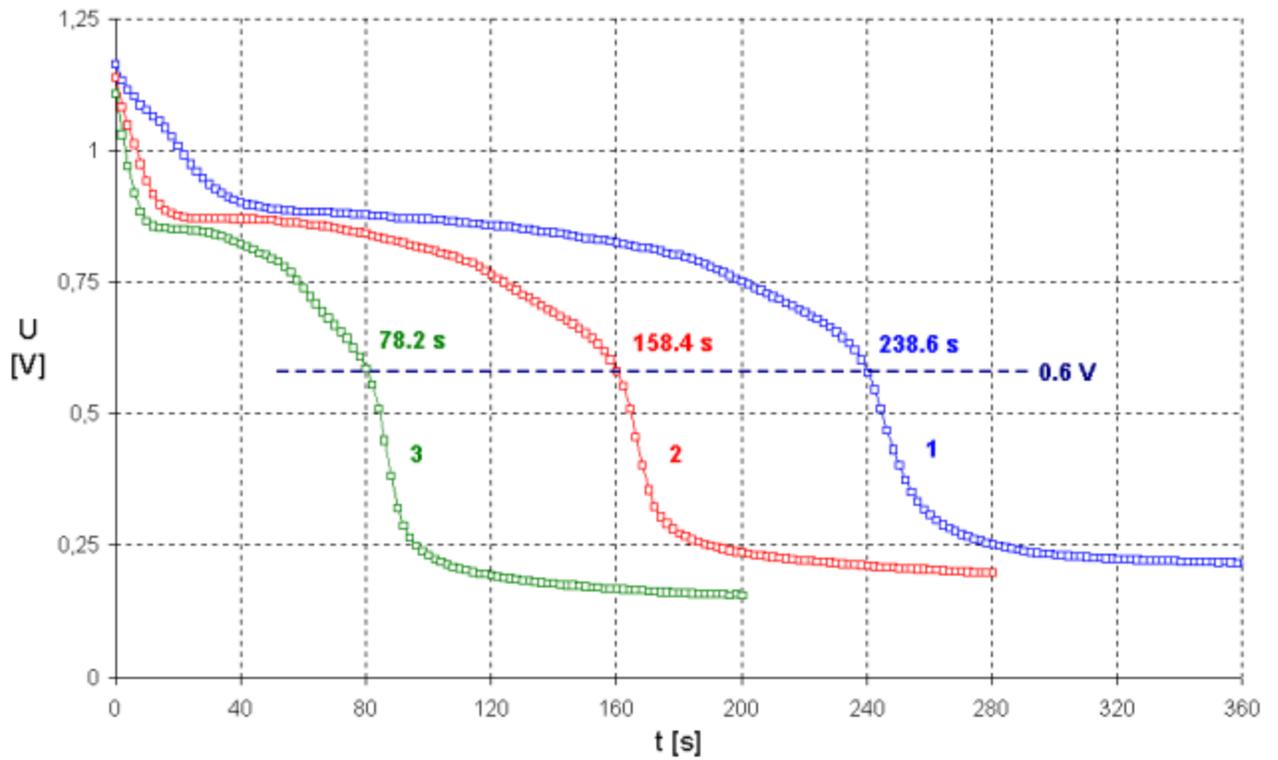
**Fig. 4: Self discharge of the Edison cell**



**Fig. 5: Real-time plot - discharge with a current of 20 mA**

**Data analysis using Excel :**

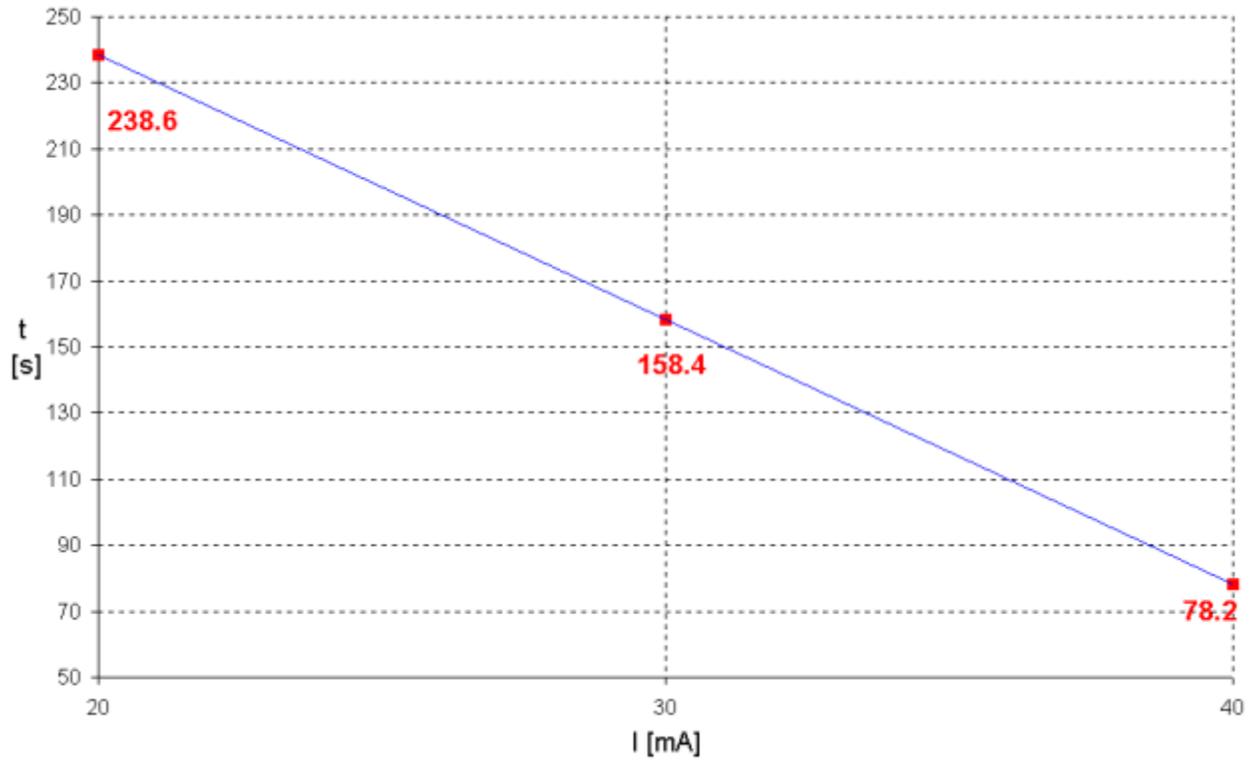
The pairs of measured values logged using the CHEMBOX/CHEMEX System are analyzed using the spread sheet program Microsoft Excel.



**Fig. 6: Discharging at 20 mA (1), 30 mA (2) und 40 mA (3)**

The voltage of the unloaded cell is approx. 1.2 V.

At the beginning of the discharge, the voltage decreases. Then it remains rather constant for some time, until it suddenly decreases within a couple of seconds. With a voltage of 0.6 V the battery is to be regarded as discharged. A linear relationship is evident between amperage and discharge time(**Fig. 7**).



**Fig. 7: Plot of amperage versus the discharge time**

In order to discharge the cell initial currents  $I_0$  are adjusted by the selection of the resistance. The results are initial voltages  $U_0$  corresponding to the currents  $I_0$ .

|               | $I_0$ [mA] | $U_0$ [V] |
|---------------|------------|-----------|
| Measurement 1 | 20         | 1.162     |
| Measurement 2 | 30         | 1.137     |
| Measurement 3 | 40         | 1.107     |

**Tab. 1: Initial currents and initial voltages when discharging**

The time-dependent currents  $I(t)$  obtained during the discharge of the battery can be computed using the following relationship

$$I(n,t,U) = U \cdot I_0 / U_0$$

The values for  $I(n,t,U)$  are determined according to the above mentioned formula (**Tab. 2**) and a plot of  $I$  versus  $t$  is permitted (**Fig. 8**).

| F5 |       | =B5*20/1,162 |        |        |   |                         |         |         |   |   |   |   |
|----|-------|--------------|--------|--------|---|-------------------------|---------|---------|---|---|---|---|
|    | A     | B            | C      | D      | E | F                       | G       | H       | I | J | K | L |
| 1  | t [s] | 20 mA        | 30 mA  | 40 mA  |   | $I = U \cdot I_0 / U_0$ |         |         |   |   |   |   |
| 2  |       |              |        |        |   |                         |         |         |   |   |   |   |
| 3  |       |              |        |        |   |                         |         |         |   |   |   |   |
| 4  |       |              |        |        |   |                         |         |         |   |   |   |   |
| 5  | 0     | 1,162        | 1,137  | 1,107  |   | 20,0000                 | 30,0000 | 40,0000 |   |   |   |   |
| 6  | 2     | 1,132        | 1,081  | 1,029  |   | 19,4836                 | 28,5224 | 37,1816 |   |   |   |   |
| 7  | 4     | 1,115        | 1,047  | 0,9695 |   | 19,1910                 | 27,6253 | 35,0316 |   |   |   |   |
| 8  | 6,04  | 1,102        | 1,012  | 0,9182 |   | 18,9673                 | 26,7018 | 33,1780 |   |   |   |   |
| 9  | 8,04  | 1,085        | 0,9738 | 0,8818 |   | 18,6747                 | 25,6939 | 31,8627 |   |   |   |   |
| 10 | 10    | 1,077        | 0,9417 | 0,8647 |   | 18,5370                 | 24,8470 | 31,2448 |   |   |   |   |
| 11 | 12    | 1,064        | 0,916  | 0,8561 |   | 18,3133                 | 24,1689 | 30,9341 |   |   |   |   |
| 12 | 14    | 1,055        | 0,8968 | 0,8518 |   | 18,1583                 | 23,6623 | 30,7787 |   |   |   |   |
| 13 | 16    | 1,042        | 0,8861 | 0,8518 |   | 17,9346                 | 23,3799 | 30,7787 |   |   |   |   |
| 14 | 18    | 1,025        | 0,8797 | 0,8497 |   | 17,6420                 | 23,2111 | 30,7028 |   |   |   |   |
| 15 | 20    | 1,008        | 0,8754 | 0,8497 |   | 17,3494                 | 23,0976 | 30,7028 |   |   |   |   |

Tab. 2: Spread sheet

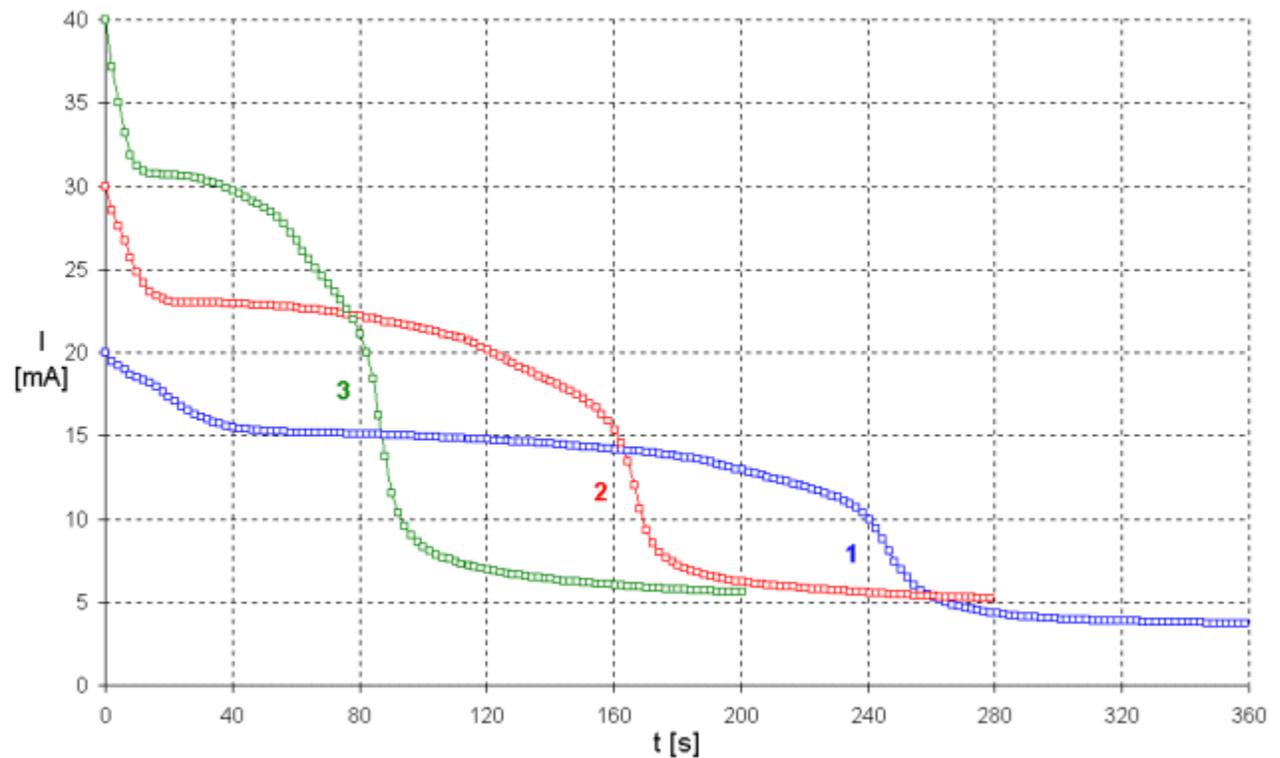


Fig. 8: Plot of amperage I versus time t

"Integration" of the current  $I(t)$  over the discharge time (time when cell voltage is 0.6 V) yields the capacity  $C$  of the battery. The capacity is found by calculating the appropriate area below the curves (Tab. 3, 4).

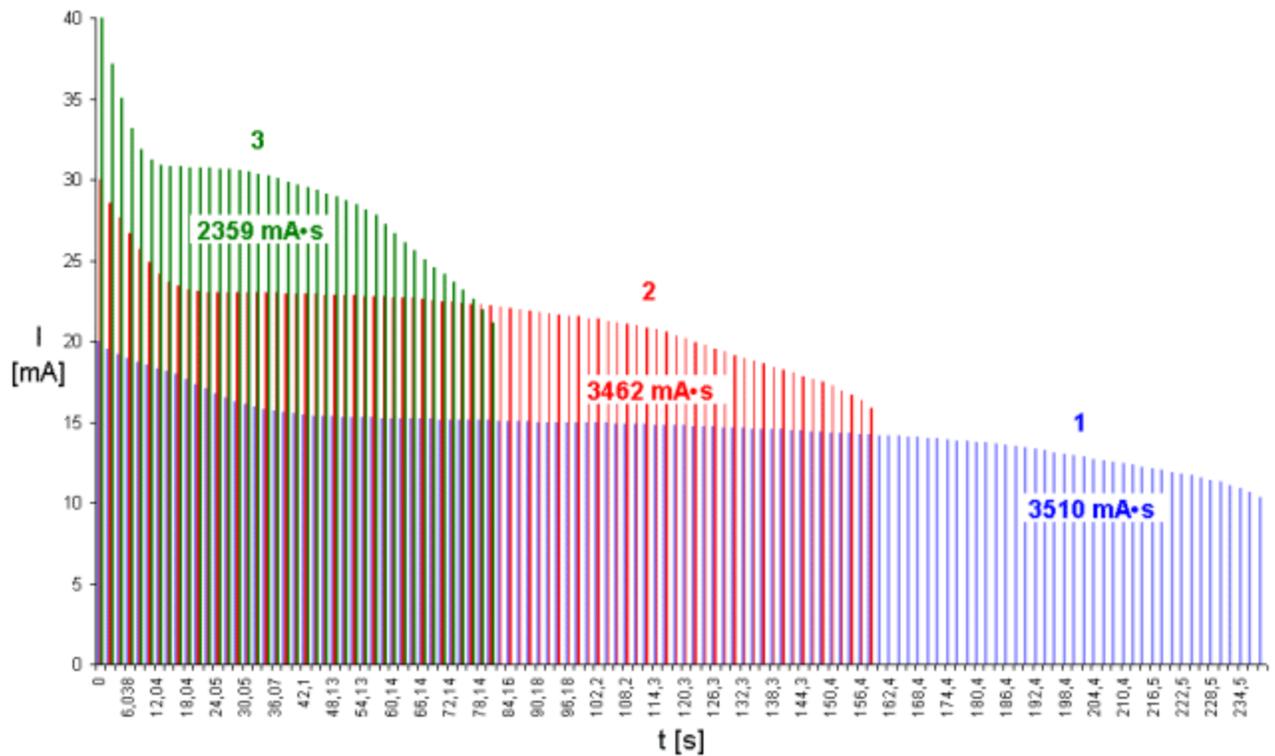
| J5 |       | =(A6-A5)*F5-(F5-F6)*(A6-A5)/2 |        |        |   |                         |         |         |   |            |           |           |
|----|-------|-------------------------------|--------|--------|---|-------------------------|---------|---------|---|------------|-----------|-----------|
|    | A     | B                             | C      | D      | E | F                       | G       | H       | I | J          | K         | L         |
| 1  | t [s] | 20 mA                         | 30 mA  | 40 mA  |   | $I = U \cdot I_0 / U_0$ |         |         |   | Capacity C |           |           |
| 2  |       |                               |        |        |   |                         |         |         |   |            |           |           |
| 3  |       |                               |        |        |   |                         |         |         |   | 3509,8065  | 3461,9861 | 2359,4178 |
| 4  |       |                               |        |        |   |                         |         |         |   |            |           |           |
| 5  | 0     | 1,162                         | 1,137  | 1,107  |   | 20,0000                 | 30,0000 | 40,0000 |   | 39,463907  | 58,493166 | 77,142981 |
| 6  | 2     | 1,132                         | 1,081  | 1,029  |   | 19,4836                 | 28,5224 | 37,1816 |   | 38,674699  | 56,147757 | 72,213189 |
| 7  | 4     | 1,115                         | 1,047  | 0,9695 |   | 19,1910                 | 27,6253 | 35,0316 |   | 38,902435  | 55,386557 | 69,539662 |
| 8  | 6,04  | 1,102                         | 1,012  | 0,9182 |   | 18,9673                 | 26,7018 | 33,1780 |   | 37,604355  | 52,343383 | 64,97561  |
| 9  | 8,04  | 1,085                         | 0,9738 | 0,8818 |   | 18,6747                 | 25,6939 | 31,8627 |   | 37,286127  | 50,641979 | 63,233713 |
| 10 | 10    | 1,077                         | 0,9417 | 0,8647 |   | 18,5370                 | 24,8470 | 31,2448 |   | 36,850258  | 49,015831 | 62,178862 |
| 11 | 12    | 1,064                         | 0,916  | 0,8561 |   | 18,3133                 | 24,1689 | 30,9341 |   | 36,471601  | 47,831135 | 61,712737 |
| 12 | 14    | 1,055                         | 0,8968 | 0,8518 |   | 18,1583                 | 23,6623 | 30,7787 |   | 36,092943  | 47,042216 | 61,557362 |
| 13 | 16    | 1,042                         | 0,8861 | 0,8518 |   | 17,9346                 | 23,3799 | 30,7787 |   | 35,576592  | 46,591029 | 61,481481 |
| 14 | 18    | 1,025                         | 0,8797 | 0,8497 |   | 17,6420                 | 23,2111 | 30,7028 |   | 34,991394  | 46,308707 | 61,405601 |
| 15 | 20    | 1,008                         | 0,8754 | 0,8497 |   | 17,3494                 | 23,0976 | 30,7028 |   | 34,402754  | 46,137203 | 61,405601 |

Tab 3: Spread sheet

| J3 |       | =SUM(J5:J124) |        |        |   |                         |         |         |   |            |           |           |
|----|-------|---------------|--------|--------|---|-------------------------|---------|---------|---|------------|-----------|-----------|
|    | A     | B             | C      | D      | E | F                       | G       | H       | I | J          | K         | L         |
| 1  | t [s] | 20 mA         | 30 mA  | 40 mA  |   | $I = U \cdot I_0 / U_0$ |         |         |   | Capacity C |           |           |
| 2  |       |               |        |        |   |                         |         |         |   |            |           |           |
| 3  |       |               |        |        |   |                         |         |         |   | 3509,8065  | 3461,9861 | 2359,4178 |
| 4  |       |               |        |        |   |                         |         |         |   |            |           |           |
| 5  | 0     | 1,162         | 1,137  | 1,107  |   | 20,0000                 | 30,0000 | 40,0000 |   | 39,463907  | 58,493166 | 77,142981 |
| 6  | 2     | 1,132         | 1,081  | 1,029  |   | 19,4836                 | 28,5224 | 37,1816 |   | 38,674699  | 56,147757 | 72,213189 |
| 7  | 4     | 1,115         | 1,047  | 0,9695 |   | 19,1910                 | 27,6253 | 35,0316 |   | 38,902435  | 55,386557 | 69,539662 |
| 8  | 6,04  | 1,102         | 1,012  | 0,9182 |   | 18,9673                 | 26,7018 | 33,1780 |   | 37,604355  | 52,343383 | 64,97561  |
| 9  | 8,04  | 1,085         | 0,9738 | 0,8818 |   | 18,6747                 | 25,6939 | 31,8627 |   | 37,286127  | 50,641979 | 63,233713 |
| 10 | 10    | 1,077         | 0,9417 | 0,8647 |   | 18,5370                 | 24,8470 | 31,2448 |   | 36,850258  | 49,015831 | 62,178862 |
| 11 | 12    | 1,064         | 0,916  | 0,8561 |   | 18,3133                 | 24,1689 | 30,9341 |   | 36,471601  | 47,831135 | 61,712737 |
| 12 | 14    | 1,055         | 0,8968 | 0,8518 |   | 18,1583                 | 23,6623 | 30,7787 |   | 36,092943  | 47,042216 | 61,557362 |
| 13 | 16    | 1,042         | 0,8861 | 0,8518 |   | 17,9346                 | 23,3799 | 30,7787 |   | 35,576592  | 46,591029 | 61,481481 |
| 14 | 18    | 1,025         | 0,8797 | 0,8497 |   | 17,6420                 | 23,2111 | 30,7028 |   | 34,991394  | 46,308707 | 61,405601 |
| 15 | 20    | 1,008         | 0,8754 | 0,8497 |   | 17,3494                 | 23,0976 | 30,7028 |   | 34,402754  | 46,137203 | 61,405601 |

Tab. 4: Spread sheet

A bar graph is selected (**Fig. 9**).



**Fig. 9: Determination of the battery capacity**

|               | $I_0$ [mA] | C [mA · s] |
|---------------|------------|------------|
| Measurement 1 | 20         | 3510       |
| Measurement 2 | 30         | 3462       |
| Measurement 3 | 40         | 2359       |

**Tab. 5: Capacity of the battery**

[http://www.chemie.uni-regensburg.de/Organische\\_Chemie/Didaktik/Keusch/chembox\\_edison-e.htm](http://www.chemie.uni-regensburg.de/Organische_Chemie/Didaktik/Keusch/chembox_edison-e.htm)