Experiment No. 35: Electrolysis

Objective

To determine the **Faraday constant** and the **electrochemical equivalent of copper** using the electrolysis method.

Topics for Preparation

1. What are the differences between the descriptions of electrical conduction in metals and in electrolytes
2. State Faraday's laws of electrolysis
3. What mass of a substance is deposited when a current of 1 ampere flows through an electrolyte for 1 second? Give the name of this quantity
4. Explain the following terms, using examples : molar mass, valency, cation, anode, cathode
5. Define: 1 ampere, 1 volt, 1 coulomb. Express these units in terms of the SI base units.
6. How should an ammeter be connected in a circuit, in series or in parallel? Explain why
7. How many copper atoms are deposited on an electrode when an electric charge equal to the Faraday constant passes through an electrolyte?
8. Electric charge **Q** is the product of electric current ***I*** and time ***t***:

$$Q = It$$

Using the law of uncertainty propagation, estimate the uncertainty of the charge determined from measurements of **I** and **t**.

Experimental Setup

1. Electrolysis vessel containing copper sulfate solution ($CuSO_4$) and copper electrodes in the form of parallel plates separated by several centimeters (Fig. 1).
2. DC power supply.
3. Ammeter.
4. Electronic balance.

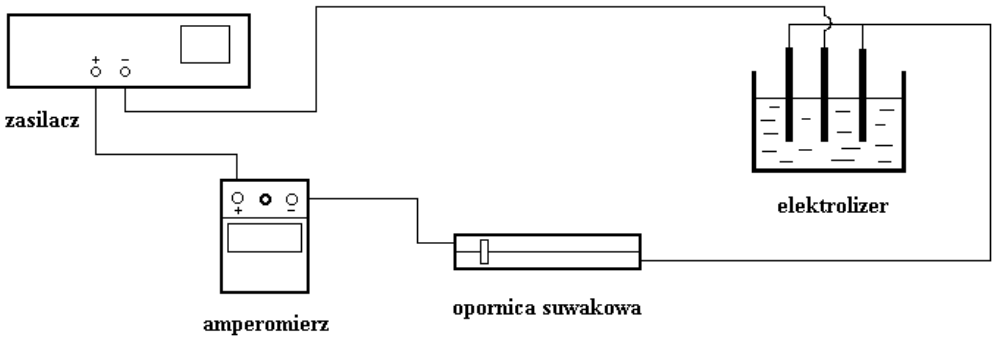


Fig. 1. Electrical circuit diagram.

Experimental Procedure

1. Assemble the circuit according to the diagram provided. Pay particular attention to the polarity of the connections. For example, the positive terminal (+) of the power supply should be connected to the positive terminal of the ammeter. Initially, set the ammeter to its highest measurement range. Once the operating current has been established during electrolysis, switch to a lower range. This reduces the risk of damaging the instrument and minimizes measurement uncertainty. The central electrode (cathode) should be connected to the negative terminal (−) of the power supply, while the outer electrodes (connected together by a wire) should be connected to the positive terminal (+).
2. Clean the cathode using sandpaper and weigh it on the electronic balance. Before weighing, remove dust by rinsing the electrode with distilled water and drying it thoroughly.
3. If instructed by the laboratory supervisor, weigh the anodes (the remaining electrodes) using the same procedure as for the cathode.
4. Mount the cathode (and anodes) in the holder and immerse the electrodes in the electrolyte.
5. After the circuit has been checked by the instructor and the electrolysis time (typically 30 minutes) and current value (approximately 0.5 A DC) have been specified, switch

on the power supply and simultaneously start the stopwatch. Use the rheostat to adjust the current to the required value.

6. During electrolysis, monitor the current and, if necessary, adjust it using the rheostat.
7. After the specified electrolysis time has elapsed, switch off the power supply, remove the electrodes from the voltameter, and detach the cathode. To remove any possible deposits, gently rinse it with denatured alcohol and then dry it carefully using a hair dryer with a low airflow. Avoid touching the surface on which copper has been deposited, as the deposited layer can easily be rubbed off.
8. Weigh the cathode.
9. If the anodes were weighed before electrolysis, weigh them again after the experiment.

3. Measurement Results

Electrolysis time [min]	t =	……..	min
Current [A]	I =	……..	A
Mass of cathode before electrolysis [g]	m_1 =	……..	g
Mass of cathode after electrolysis	m_2 =	……..	g
Mass of deposited copper [g]	$m = m_2 - m_1$ =	……..	g
Total mass of anodes before electrolysis	M_1 =	……..	g
Total mass of the anodes after electrolysis	M_2 =	……..	g
Change in the total mass of the anodes	$M = M_1 - M_2$ =	……..	g

Instrument Uncertainty Data

Ammeter class: .....

Ammeter range used: .....

Balance limiting (rated) uncertainty: $\boldsymbol{\Delta m}$ =.....

Balance standard uncertainty: $\boldsymbol{u(m)}$ =.....

4. Data Analysis

Calculate the mass of copper deposited on the cathode during electrolysis

m = ...

Calculate the change in the mass of the anodes during electrolysis

M = ...

Using equation (4), calculate the electrochemical equivalent of copper

k = ...

Using the obtained value of ***k***, calculate the experimental value of the **Faraday constant** from e**quation (5)**

F = ...

Using the experimentally determined Faraday constant, calculate the elementary charge

e = ...

Uncertainty Analysis

Note: Consider what value should be assigned to the uncertainty of the cathode mass measurement (and, if applicable, the anode mass measurement). This uncertainty may be affected by rinsing the electrodes with denatured alcohol. It may also result from electrolyte contamination and incomplete drying of the electrodes. Taking these factors into account, to what precision (how many significant figures) should the mass of copper deposited during electrolysis be reported?

m = ...

The uncertainty of the mass of copper deposited during electrolysis is assumed to be

u(m) = ...

Note: If the anodes were weighed during the experiment, calculate the change in their mass. It may be assumed that the uncertainty of the anode mass measurement, ***u(M),*** is equal to the uncertainty ***u(m).*** Compare the change in the mass of the anodes with the change in the mass of the cathode. Are these quantities equal within the limits of uncertainty? Based on the obtained results, can the law of conservation of mass be formulated?

Calculate the uncertainty of the electric charge that passed through the electrolyte. To do so, calculate the uncertainty of the current measurement, knowing that it is equal to

u(I) = (ammeter accuracy class × measurement range) / 100
= ....

u(Q) = ...

Estimate the uncertainty of the time measurement. Depending on its magnitude, one may:

a) include it in the subsequent calculations, or

b) assume that, due to its small value (relative uncertainty equal to ..... %), it is negligible compared with, for example, the uncertainty of the mass measurement, and therefore omit it from the subsequent calculations.

Since the electrochemical equivalent of copper was calculated from an equation $k = \frac{m}{I\,t}$ containing only multiplication and division operations, the combined relative uncertainty is equal to the geometric sum of the relative uncertainties of the quantities appearing in the functional dependence.

$$\frac{u(k)}{k} = \sqrt{\left[\frac{u(m)}{m}\right]^2 + \left[\frac{u(I)}{I}\right]^2 + \left[\frac{u(t)}{t}\right]^2},$$

(see *Processing of Measurement Results*, Section 1.5, Equation 1.15). If the uncertainty of the time measurement is not included in the calculations, the corresponding term should be omitted from the formula.

The relative and absolute uncertainties of the electrochemical equivalent of copper ***k*** are

u(k)/k = ...

u(k) = ...

The Faraday constant and the elementary charge are calculated using equations (4) and (5), in which the uncertain quantity ***k*** is multiplied (or divided) by the tabulated values of N_a and ***e***, whose uncertainties are negligibly small. According to the law of propagation of relative uncertainties, the relative uncertainties ***u(F)/F*** and ***u(e)/e*** are equal to the previously calculated relative uncertainty ***u(k)/k***. Formally, this follows from the derivation (for equation (4)):

$$\frac{u(F)}{F} = \sqrt{\left[\frac{u(\mu)}{\mu}\right]^2 + \left[\frac{u(k)}{k}\right]^2} = \sqrt{\left[\frac{u(k)}{k}\right]^2} = \frac{u(k)}{k}.$$

In other words, if the relative uncertainty of ***k*** is, for example, 2.6%, then the values of both ***F*** and ***e*** are known with the same relative uncertainty. Therefore, the absolute uncertainties of the Faraday constant and the elementary charge can be calculated as

u(F) = ...

u(e) = ...

The obtained results should be summarized in the table below.

Quantity	**Tabulated value**	**Experimental value**	**Difference**	**Uncertainty**	**Relative uncertainty [%]**
***k* [.....]**					
***F* [.....]**					
***e* [.....]**					

Summary Conclusions: