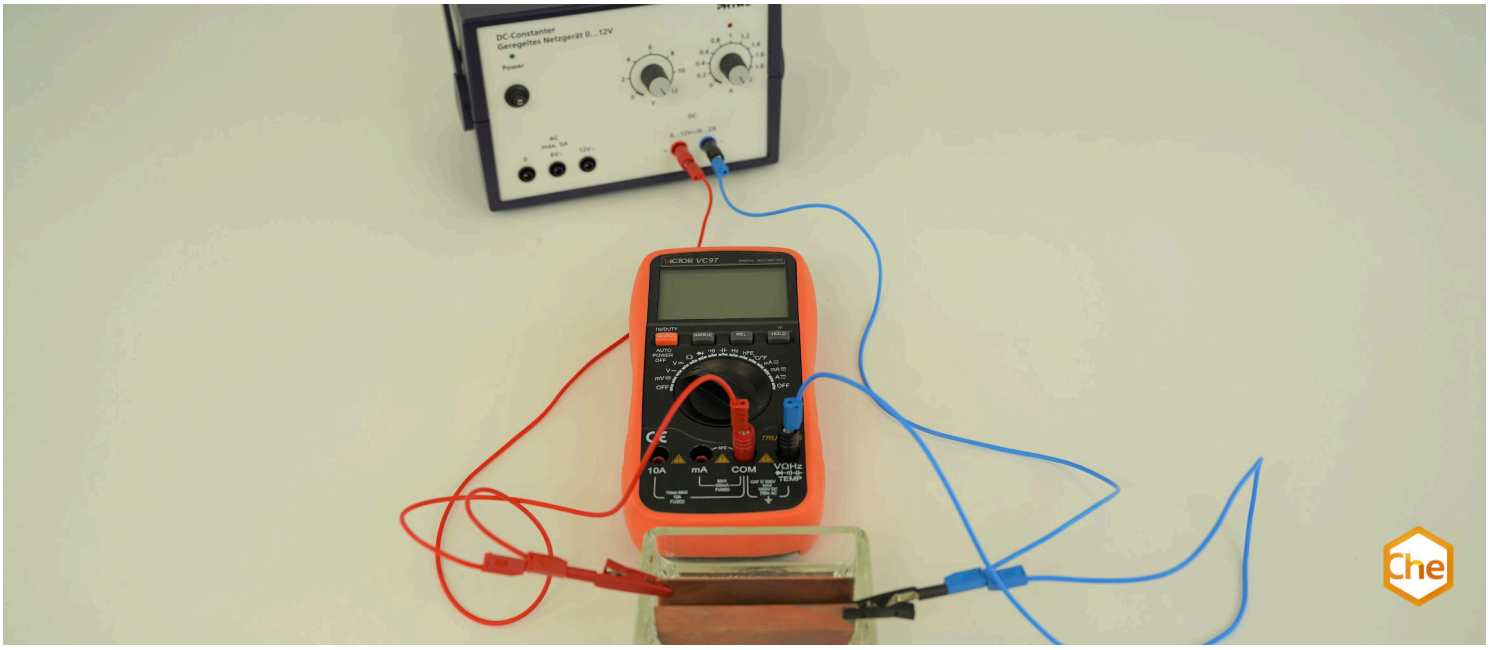
Overvoltage in electrolysis



With this experiment, students learn about the principle of overvoltage in redox reactions using electrolysis as an example.

Chemistry > Physical chemistry > Electrochemistry > Electrolysis

Difficulty level	Group size	Preparation time	Execution time
easy	1	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/61a8dfbc22e1e50003a26e2c

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Teacher information

Application

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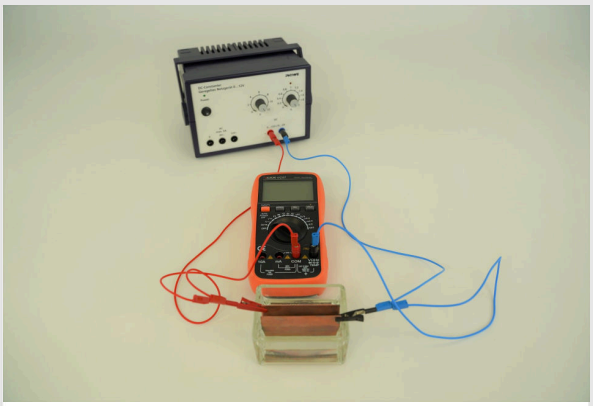

Experiment setup

In any electrolysis, electrical energy must be supplied. However, electrolytic decomposition does not start until a certain voltage is reached. This voltage value is also referred to as the decomposition voltage (the electrolysis reactions only start from this voltage).

The decomposition stress can be determined with the help of Nernst's equation. However, this calculated value is lower than the measured decomposition voltage. The difference between the measured and calculated voltage corresponds to the overvoltage.

In this experiment, water is electrolyzed while slowly increasing the applied DC voltage.

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Other teacher information (1/4)

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Previous knowledge

The students should already be familiar with the principle of electrolysis. They should also already be familiar with charge transport, current strength and conductivity.

Scientific Principle

Electrode polarization and the presence of overvoltage are important concepts for understanding electrode processes. They are based on the fact that galvanic cells always supply current even below the equilibrium voltage (emf) and that an applied voltage greater than the equilibrium voltage (emf) is required for electrolysis. Some important electrochemical devices (e.g. the lead accumulator) and electroanalytical techniques (e.g. polarography) use the inhibition (high overvoltage) of certain electrode reactions.

Other teacher information (2/4)

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Learning objective

With this experiment, students learn about the principle of overvoltage in redox reactions using electrolysis as an example.

Tasks

Students perform two electrolyses: one in water and one in dilute sulfuric acid.

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Other teacher information (3/4)

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Further information

Electrical energy must be supplied for every electrolysis. Only above a certain voltage does any electrolytic decomposition begin. This voltage value is also called decomposition voltage (only from this voltage the electrolysis reactions start). This value is higher than the difference of the normal potentials. This is due to the fact that electrolysis produces two galvanic half-cells, which also supply voltage. However, this voltage has the opposite effect to the applied DC voltage.

The decomposition stress can be calculated using Nernst's equation (for standard conditions, the stress can be calculated by the difference of the standard potentials). This calculated decomposition voltage is usually lower than the measured decomposition voltage. This is due to the so-called overvoltage. The overvoltage is the difference between the measured and calculated decomposition voltage.

Other teacher information (4/4)

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Further information

If the electrolysis of water is carried out under standard conditions, the decomposition voltage can be determined via the standard potentials. The potentials are 0.00 V (hydrogen) and 1.23 V (oxygen). The difference (1.23 V) corresponds to the calculated decomposition voltage. You must therefore apply at least 1.23 volts DC to electrolyse water.

However, a higher experimentally determined decomposition voltage is observed. This is due to the overvoltage and depends on the electrode material. If gases are formed during electrolysis (as in the electrolysis of water), the required decomposition voltage increases. One of the reasons for this is that physical or chemical reactions can take place between the gases and the metal electrodes on the surface.

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Safety instructions

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- Wear protective goggles and gloves.
- For the H- and P-phrases please refer to the corresponding safety data sheets.
- The general instructions for safe experimentation in science lessons apply to this experiment.

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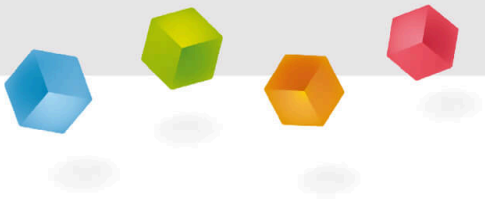

Student Information

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Motivation

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Aluminium beverage can

You use many metals every day - be it the beverage can, the circuit boards in your computer, the galvanized garden gate. Many of these metals have their origin in electrolysis: it is one of the main processes for the production of many metals.

The electrolysis of water often begins (depending on the experimental setup) only at 2 volts. This value is called the decomposition voltage. The decomposition voltage can be calculated, but is usually lower than the measured decomposition voltage. The difference between the measured and calculated decomposition voltage corresponds to the overvoltage.

Tasks

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1. Perform electrolysis with copper electrodes in water.
2. Perform electrolysis with copper electrodes in dilute sulfuric acid.
3. Write down your observations.

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Equipment

Position	Material	Item No.	Quantity
1	Protecting glasses, clear glass	39316-00	1
2	Connecting cord, 2 mm-plug, 5A, 250 mm, red	07355-01	1
3	Connecting cord, 2 mm-plug, 5A, 250 mm, blue	07355-04	1
4	Connecting cord, 2 mm-plug, 5A, 500 mm, red	07356-01	1
5	Connecting cord, 2 mm-plug, 5A, 500 mm, blue	07356-04	1
6	Alligator clip, insulated, 2 mm socket, 2 pcs.	07275-00	3
7	Graphite electrode,d=5,l=150,6pc	44510-00	1
8	Digital multimeter, 750V AC/DC, 10A AC/DC, 40MΩ, 100mF, 30 MHz, -20...1000°C, Auto range	07123-12	1
9	Reducing plug 4mm/2mm socket, 2	11620-27	2
10	Flat battery, 4.5 V	07496-01	1
11	Set Strip electrode (Al, Fe, Pb, Zn, Cu)	07856-00	1
12	Copper electrode, 76 mm x 40 mm	45212-00	1
13	Trough, grooved, w/o lid	34568-01	2
14	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
15	Sulphuric acid, 10%, tech.gr., 1000 ml	31828-70	1

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Structure and implementation (1/2)

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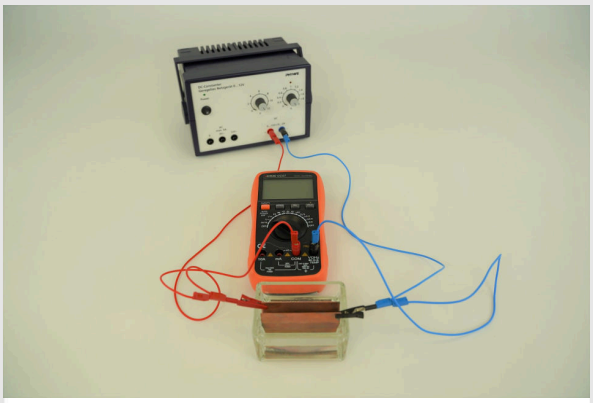
Experiment 1: Copper electrodes in water

- Fill the grooved trough with distilled water.
- Insert the two copper sheets, which act as electrodes, into the grooved trough.
- Connect one cable to each plate using the alligator clips. Connect the cables to the + and - terminals of the power supply.
- Also, connect the multimeter to both electrodes as shown in the figure to the right.
- Switch on the power supply and slowly increase the voltage in 0.5 V steps, up to about 4 volts.



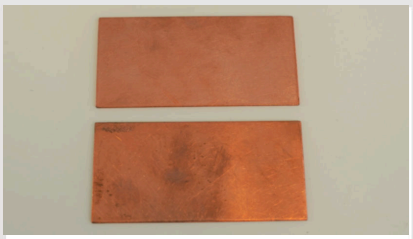
Experiment setup

Structure and implementation (2/2)

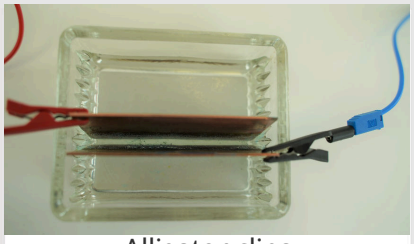
PHYWE

Experiment 2: Copper electrodes in sulphuric acid

- Replace the distilled water in the grooved trough with dilute sulfuric acid (1 mol/L).
- Insert the two copper sheets, which act as electrodes, into the grooved trough. If they are tarnished, use lubricating gel paper to get them shiny again (picture top right).
- Connect one cable to each plate using the alligator clips. The electrodes should not touch each other (picture below right). Connect the cables to the + and - pole of the power supply.
- Also connect the voltmeter to both electrodes. Switch on the power supply and slowly increase the voltage in 0.5 V steps until you see the first electrolysis reactions.



Copper sheets



Alligator clips

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Report

Task 1

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Drag the words into the correct boxes!

In chemistry, _____ is a potential difference or voltage difference between the _____ potential of the half-cells and the potential (voltage) at which _____ takes place. The overvoltage is therefore the _____ between the calculated decomposition voltage and the decomposition voltage measured in the experiment.

electrolysis
calculated
difference
overvoltage

Check

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Task 2

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Choose the correct statements.

- [ ] One reason for the overvoltage is the temperature increase of the electrolyte during the electrolysis reaction.
- [ ] The minimum decomposition stress is: $\Delta E = E^0(\text{cathode}) - E^0(\text{anode}) = 0.00\ V - 1.23\ V = -1.23V$
- [ ] One reason for the overvoltage is the ohmic resistance of the electrolyte.
- [ ] Overvoltage occurs mainly in electrolysis reactions in which gases are produced.

Check

Task 3

PHYWE

Choose the correct statements.

- [ ] Electrolysis requires an applied voltage that is greater than the potential difference of both half cells (EMF).
- [ ] Galvanic cells always supply current even below the potential difference of both half cells (EMF).
- [ ] For an electrolysis an applied voltage is necessary, which is smaller than the potential difference of both half cells (EMF).
- [ ] Galvanic cells do not supply current below the potential difference of both half cells.

Check

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Slide	Score / Total
Slide 15: Overvoltage defined	0/4
Slide 16: Causes of overvoltage	0/3
Slide 17: Current and overvoltage	0/2

Total 0 / 9

Solutions Repeat

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