Electrochemical voltage series of metals from potential differences of half cells with Cobra SMARTsense

In the course of the experiment, the students learn about the "electrochemical voltage series" of metals.

Chemistry › Physical chemistry › Electrochemistry › Galvanic elements, fuel cells

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	20 minutes

This content can also be found online at:

https://www.curriculab.de/c/68d6634b426ea700023c0c24

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Teacher information

Application

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The discovery and further development of galvanic elements, better known as batteries, is of great importance to mankind. They enable the mobile power supply of numerous electrical devices and therefore have a decisive influence on our current standard of living.

The combination of different half cells into galvanic cells creates different DC voltages. These voltage differences make it possible to galvanise metals in a specific order - the **electrochemical voltage series** - to arrange. Knowledge of this sequence also makes it possible to recognise potential differences between metals. **indirect** without the need for direct measurement.

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Other teacher information (1/7)

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Prior knowledge

Students should have worked with galvanic elements (Daniell element) in theory and practice. They should also already have a basic understanding of voltage series in electrochemistry.

Principle

The combination of different half cells to form galvanic cells leads to different DC voltages. By observing these voltage differences, metals can be arranged in a certain order to form an electrochemical voltage series.

Other teacher information (2/7)

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Learning objective

In the course of the experiment, the students should familiarise themselves with the "electrochemical voltage series" of metals and be able to assess which metal is "more noble" and which is "less noble".

Tasks

The students are asked to make 4 different half cells from $Zn|Zn^{2+}$, $Cu|Cu^{2+}$, $Pb|Pb^{2+}$ and $Ag|Ag^{+}$ set up. They should combine the half-cells in pairs to form galvanic cells and measure the resulting DC voltages. The metals can then be categorised according to their electrochemical potential based on the voltages.

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Other teacher information (3/7)

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The measured voltages result in a clear sequence of the four metals with regard to their **Striving for solutions** or their **electrochemical potential**. This shows that zinc has the strongest endeavour to change to the ionic state, while silver shows this endeavour to be the least pronounced. Accordingly **Zinc** compared to all other metals **negative pole**, **silver** on the other hand always **positive pole**.

The metals lead and copper show a changing behaviour:

- Lead is positive towards zinc, but negative towards copper and silver
- Copper is positive towards zinc and lead, but negative towards silver.

Other teacher information (4/7)

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The measured voltages between the metal pairs result in the following **Potential differences**:

Metal pair	Potential difference $\Delta E \;/\; \mathrm{V}$
Ag - Cu	$+0,45$
Cu - Pb	$+0,47$
Pb - Zn	$+0,63$
Ag - Pb	$+0,92$
Zn - Ag	$+1,55$
Zn - Cu	$+1,01$

These values show that the potential difference between two metals can also be **Calculate indirectly** by adding the differences of several intermediate steps. For example, the potential difference between **Zinc and silver** not only directly, but also from the sum of several partial voltages:

$\Delta E_{\text{Zn-Ag}} = \Delta E_{\text{Ag-Cu}} + \Delta E_{\text{Cu-Pb}} + \Delta E_{\text{Pb-Zn}} = 1,55\ \mathrm{V}$ or

$\Delta E_{\text{Zn-Ag}} = \Delta E_{\text{Ag-Pb}} + \Delta E_{\text{Pb-Zn}} = 1,55\ \mathrm{V}.$

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Other teacher information (5/7)

This agreement confirms that the potential differences **additive** and unknown values can also be derived in this way.

The order of all metals in the order of their potentials finally results in the so-called **Electrochemical voltage series**. It makes it possible to make statements about the redox behaviour of metals and to plan or analyse galvanic elements in a targeted manner, even without testing every combination experimentally.

Other teacher information (6/7)

The solutions can be produced for everyone to save chemicals!

- **Copper sulphate solution** $(0,1\,\mathrm{mol/l})$: Add $12,5\,\mathrm{g}$ Copper sulphate to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.
- **Lead nitrate solution** $(0,1\,\mathrm{mol/l})$: Add $16,5\,\mathrm{g}$ Lead nitrate to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.
- **Zinc sulphate solution** $(0,1\,\mathrm{mol/l})$: Add $14,4\,\mathrm{g}$ Zinc sulphate to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.
- **Silver nitrate solution** $(0,1\,\mathrm{mol/l})$ Add $8,5\,\mathrm{g}$ Silver nitrate to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.

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Other teacher information (7/7)

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The solutions can be produced for everyone to save chemicals!

- **Potassium nitrate solution** $(1\ \mathrm{mol/l})$: Add $51\ \mathrm{g}$ Potassium nitrate to $250\ \mathrm{ml}$ distilled water. Mix well and fill up to $500\ \mathrm{ml}$ with distilled water.

When using this approach variable, a $600\ \mathrm{ml}$ beaker can be used. You can find this in the PHYWE webshop.

Safety instructions

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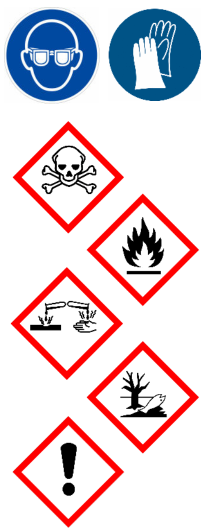

- The general instructions for safe experimentation in science lessons apply to this experiment.
- All persons in the room must wear safety goggles during the experiment!
- Lead and lead nitrate are toxic by inhalation and ingestion with a risk of cumulative effects. They can also be absorbed through the skin. Avoid any contact of the chemicals with the eyes and skin.
- For H and P phrases, please refer to the safety data sheet of the respective chemical.

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Student information

Motivation

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An important milestone for mankind was the discovery and further development of so-called galvanic elements, better known as batteries.

Through the **Combination of different half cells** galvanic cells are created that generate different DC voltages. These **Voltage differences** make it possible to arrange metals in a certain order according to their electrochemical behaviour, the so-called electrochemical voltage series.

Knowledge of this sequence and the resulting **Potential differences** also allows stresses between metals to be **indirect** without the need for direct measurement.

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Tasks

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How can metals be categorised according to their electrochemical potential?

1. Build 4 half cells at a time: $Zn|Zn^{2+}$, $Cu|Cu^{2+}$, $Pb|Pb^{2+}$, $Ag|Ag^{+}$
2. Combine the half cells in pairs to form galvanic cells (6 combinations in total).
3. Measure the resulting DC voltages.
4. Classify the metals according to their electrochemical potential (from the least noble to the most noble metal) using the voltages.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense Voltage - Sensor for measuring electrical voltage ± 30 V (Bluetooth + USB)	12901-01	1
2	Connecting cord, 2 mm-plug, 5A, 500 mm, red	07356-01	1
3	Connecting cord, 2 mm-plug, 5A, 500 mm, blue	07356-04	1
4	Reducing plug 4mm/2mm socket, 2	11620-27	1
5	Alligator clip, insulated, 2 mm socket, 2 pcs.	07275-00	1
6	Set Strip electrode (Al, Fe, Pb, Zn, Cu)	07856-00	1
7	Emery paper, medium	01605-00	1
8	Silver foil, 150 x150 x 0.1 mm, 25g	31839-04	1
9	Beaker, Borosilicate, tall form, 50 ml	46025-00	5
10	Dropping bottle,plastic,50ml	33920-00	1
11	Block with 8 holes, d = 40 mm	37682-00	1
12	Coverage f.cell-meas.bloc,8 piec.	37683-00	1
13	Copper-II sulphate,cryst. 250 g	30126-25	1
14	Zinc sulphate 7-hydr. 250 g	30249-25	1
15	Potassium nitrate 250 g	30106-25	1
16	Silver nitrate, cryst. 25 g	30222-04	1
17	Water, distilled 5 l	31246-81	1
18	Chromatographic paper 100 stripes	32972-00	1
19	Protecting glasses, clear glass	39316-00	1

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Additional material

Position	Equipment	Article no.	Quantity
1	Tweezers	64610-01	1

Preparation

- **Copper sulphate solution** $(0,1\,\mathrm{mol/l})$: Add $1,25\,\mathrm{g}$ Copper sulphate to $25\,\mathrm{ml}$ distilled water. Mix well and apply to $50\,\mathrm{ml}$ Fill up with distilled water.
- **Lead nitrate solution** $(0,1\,\mathrm{mol/l})$: Add $1,65\,\mathrm{g}$ Lead nitrate to $25\,\mathrm{ml}$ distilled water. Mix well and fill up to $50\,\mathrm{ml}$ with distilled water.
- **Zinc sulphate solution** $(0,1\,\mathrm{mol/l})$: Add $1,44\,\mathrm{g}$ Zinc sulphate to $25\,\mathrm{ml}$ distilled water. Mix well and fill up to $50\,\mathrm{ml}$ with distilled water.
- **Silver nitrate solution** $(0,1\,\mathrm{mol/l})$Add $0,85\,\mathrm{g}$ Silver nitrate to $25\,\mathrm{ml}$ distilled water. Mix well and fill up to $50\,\mathrm{ml}$ with distilled water.
- **Potassium nitrate solution** $(1\,\mathrm{mol/l})$: Add $5,1\,\mathrm{g}$ Potassium nitrate to $25\,\mathrm{ml}$ distilled water. Mix well and fill up to $50\,\mathrm{ml}$ with distilled water.

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Setup (1/3)

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For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check whether your device (smartphone, tablet, desktop PC) is running **Bluetooth activated** is.

iOS

Android

Windows

Setup (2/3)

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Moisten two salt bridges one after the other in the potassium nitrate solution using tweezers and place them as a bridge between the measuring cells in the measuring cell block (see figure).

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Setup (3/3)

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Fill measuring cells 1 to 4 with the corresponding metal salt solutions (see illustration).

Place a measuring cell cover on each measuring cell.

Take a look at the electrodes: If the metal has oxidised due to storage, use a piece of sandpaper to remove the oxide layer. *Never use the lead electrode!*

Then insert the specified metal electrodes into the corresponding measuring cells: Zinc, copper, silver and lead.

Note: The silver electrode is cut out of the sheet in the same size as the other electrodes.

Procedure (1/6)

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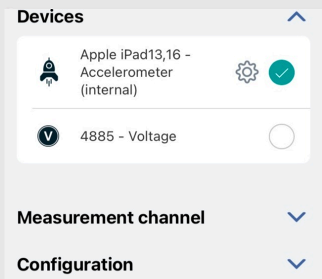
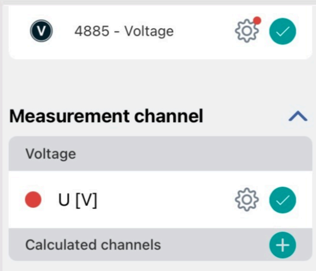
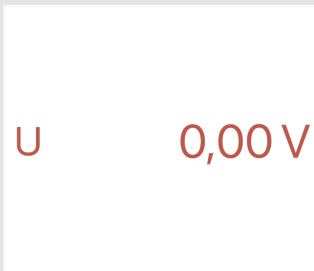
- Start the measureAPP on a mobile device.
- Press the start button on the sensor for approx. 3 seconds.
- Connect the sensor by tapping ◯ next to the description of the sensor in the measureAPP.
- Set the measured value display by tapping 0.0 above the diagram.







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Procedure (2/6)

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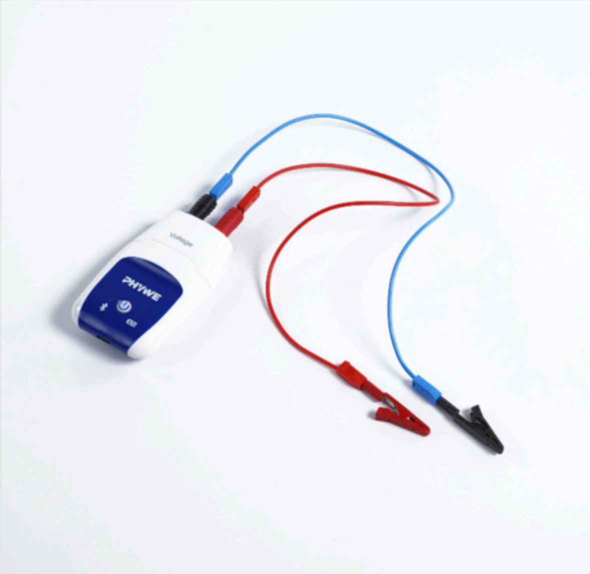
Note the colour of the connections below: blue (negative pole) always to blue (black) and red (positive pole) always to red!

As shown on the following slide, connect the crocodile clips to the metal electrodes and the leads to the Cobra SMARTsense Voltage Sensor using reducing plugs.



Procedure (3/6)

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Experimental part 1

Further details on the implementation can be found on the following slides.

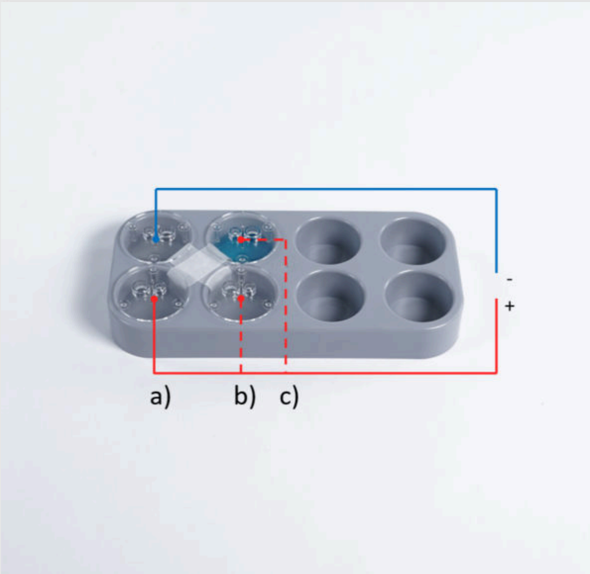
Note all measured voltages on foil **Procedure (6/6)**.

a) Connect the negative terminal to the zinc electrode and the positive terminal to the lead electrode.

The negative pole remains connected to the zinc electrode.

b) Connect the positive terminal to the silver electrode.

c) Connect the positive terminal to the copper electrode.



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Procedure (4/6)

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Experimental part 1

a)

b)

c)

Procedure (5/6)

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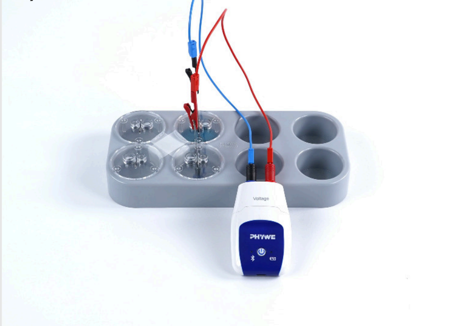
Experimental part 2
Connect the negative terminal to the lead electrode and measure the voltage against the silver and copper electrodes.

Experimental part 3
Connect the copper electrode to the negative pole and measure the voltage against the silver electrode.

2 a)

2 b)

3)



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Procedure (6/6)

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Note all measured voltages on this slide.

Experimental part 1

Electrode pair	Voltage/ V
Zn/Pb	
Zn/Cu	
Zn/Ag	

Experimental part 2

Electrode pair	Voltage/ V
Pb/Cu	
Pb/Ag	

Experimental part 3

Electrode pair	Voltage/ V
Cu/Ag	

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Report

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Task 1

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What is the order of all metals in the order of their potentials?

- The order of all metals in the order of their potentials results in a galvanic series.
- The order of all metals in the order of their potentials results in an electrochemical current series.
- The order of all metals in the order of their potentials results in an electrochemical voltage series.

Check

Task 2

PHYWE

Which of the four metals is the negative pole and which is the positive pole?

- Silver always forms the negative pole in relation to the other three metals, while zinc always forms the positive pole.
- Lead always forms the negative pole in relation to the other three metals, copper always forms the positive pole.
- Zinc always forms the negative pole in relation to the other three metals, while silver always forms the positive pole.

Check

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Task 3

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How do copper and lead behave in comparison to other metals?

- [ ] Lead and copper change their polarity depending on the type of metal with which they are combined to form a galvanic cell.
- [ ] None of the answers is correct.
- [ ] Copper is positive towards zinc and lead, but negative towards silver.
- [ ] Lead is positive towards zinc, but negative towards copper and silver.

Check

Slide	Score / Total
Slide 27: Potential sequence	**0/1**
Slide 28: Pole 4 Metals	**0/1**
Slide 29: Positive negative	**0/3**

Total amount **0/5**

Solutions Repeat

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