

# Preparation of a simplified standard hydrogen electrode and measurement of some standard potentials with Cobra SMARTsense



In the course of the experiment, the students will produce a simplified standard hydrogen electrode. The term "standard potential" is also discussed further.

Chemistry	Physical chemistry	Electrochemistry	Galvanic elements, fuel cells
 Difficulty level	 Group size	 Preparation time	 Execution time
medium	2	10 minutes	30 minutes

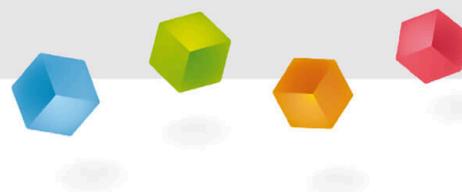
This content can also be found online at:



<https://www.curriculab.de/c/68a85e8ea65c99000273a908>

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## Teacher information



## Application

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The potential differences between metals can be measured in galvanic cells as electrical voltages. These voltages provide information about the different reduction and oxidation capacities of the metals. By combining different half cells with a constant reference electrode, a standard electrode potential can be assigned to each redox system.

As all voltages are measured relative to this reference electrode, the results are comparable. The standard hydrogen electrode serves as the reference electrode here. On this basis, a voltage series is created that supports the understanding of redox processes and the structure of galvanic cells in the classroom.

## Other teacher information (1/8)

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## Prior knowledge



The students should have worked with galvanic elements in theory and practice. They should also know what a standard hydrogen electrode and standard potentials are.

## Principle



Using the standard potentials, the potential differences or voltages between all metal combinations can be easily calculated using the following equation:

$$\Delta E = E_{\text{Kathode}} - E_{\text{Anode}}$$

## Other teacher information (2/8)

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## Learning objective



In the course of the experiment, the students will produce a simplified standard hydrogen electrode (SHE) so that an understanding of its functional principle and structure as well as the "standard potential" is created.

The comparison of the potential differences of different metals in relation to the SHE provides information about the reduction or oxidation capacity of these metals.

## Tasks

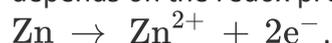


A platinum electrode is to be charged with hydrogen gas by electrolysis of sulphuric acid. This electrode is then to be combined with 4 half cells of different metals to form galvanic cells. The resulting voltages are measured and recorded in a voltage series according to magnitude and sign.

## Other teacher information (3/8)

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In the "Electrochemical voltage series" experiment, it was observed that different DC voltages are generated between the different metals as soon as they are combined in galvanic cells. These voltages are the quantitative expression of the potential differences between the interconnected half-cells. The potential depends on the redox processes of the metals in the solution. This applies to zinc, for example:



The greater the potential of a metal to dissolve, the further to the right the equilibrium of such a redox process is. However, since it is not possible to measure this solubility or the potential of a metal in a half cell alone, it is not possible to assign it a specific order of magnitude without further ado. As the experiment "Voltage series (redox series) of metals" P7400669 showed, however, the differences between the potentials of different metals can be measured if they are combined to form galvanic cells.

## Other teacher information (4/8)

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Each metal (and other redox pairs) can be assigned a relative potential value by combining a metal with an identical reference electrode to form a galvanic cell. The so-called standard hydrogen electrode (SHE) was defined as such a reference electrode.

It consists of a platinum sheet coated with platinum black, which is 1 M hydrochloric acid is immersed. A fine-bubble hydrogen stream is generated at normal pressure (1013 mbar) over the electrode. The measurement takes place at 25 °C. The catalytic effect of the platinum causes an adsorbed layer of atomic hydrogen to form on the surface - the electrode becomes a hydrogen electrode.

The following redox process can take place at this electrode:



The standard potential of this electrode is arbitrarily set to 0,00 V and serves as a reference value for all other redox systems.

## Other teacher information (5/8)

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If a metal half cell is connected to the standard hydrogen electrode (SHE) to form a galvanic cell, the electrical voltage between the two electrodes can be measured. As the potential of the hydrogen electrode is by convention 0,00 V the measured voltage corresponds directly to the standard potential of the analysed metal or redox system.

The voltages determined in this way - in relation to the defined hydrogen potential - are called standard potentials. They enable a comparative categorisation of different redox pairs with regard to their tendency to accept or release electrons.

In this student experiment, a simplified version is used instead of the technically complex SHE. It can be produced with simple means and still provides measured values that are very close to the literature values: Here, the electrode is not coated with platinum black, sulphuric acid is used instead of hydrochloric acid and there is no continuous gas feed and the hydrogen pressure is not tested.

## Other teacher information (6/8)

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The table contains the standard potentials of selected elements.

Fabric	Standard potential $E^\circ / \text{V}$	Redox system
Zinc (Zn)	-0,75 until -0,76	$\text{Zn}^{2+} + 2e^-$
Lead (Pb)	-0,12 until -0,13	$\text{Pb}^{2+} + 2e^-$
Hydrogen (H)	$\pm 0$	$\text{H}^+ + e^-$
Copper (Cu)	+0,34 until +0,35	$\text{Cu}^{2+} + 2e^-$
Silver (Ag)	+0,79 until +0,80	$\text{Ag}^+ + e^-$

## Other teacher information (7/8)

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**The solutions can be produced for everyone to save chemicals!**

- **Copper sulphate solution (1 mol/l):** Add 125 g Copper sulphate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.
- **Lead nitrate solution (1 mol/l):** Add 165 g Lead nitrate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.

**Optional production of sulphuric acid (0,5 mol/l):** Pour into a beaker 100 ml of distilled water. Pipette 14 ml of 96% sulphuric acid and fill up to 500 ml with distilled water.

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

## Other teacher information (8/8)

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**The solutions can be produced for everyone to save chemicals!**

- **Zinc sulphate solution (1 mol/l):** Add 144 g Zinc sulphate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.
- **Silver nitrate solution (1 mol/l)** Add 85 g Silver nitrate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.
- **Potassium nitrate solution (1 mol/l):** Add 51 g Potassium nitrate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.

When using this approach variable, a 600 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.
- Zinc sulphate solutions of the concentration  $c = 1,0 \text{ mol/l}$  and sulphuric acid solutions of the concentration  $c = 0,5 \text{ mol/l}$  have an irritant effect.
- 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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### Why we deal with galvanic cells:

Batteries have become an integral part of our everyday lives - whether in smartphones, remote controls or e-bikes. They enable us to use electrical energy flexibly wherever we are. There is a simple chemical principle behind this practical technology: the **galvanic cell**.

Things get exciting when you combine different metals with each other. This creates measurable voltages - depending on how "ready" a metal is to release electrons. We utilise precisely these differences in the experiment and learn how chemical energy is converted directly into electrical energy.

## Tasks

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Prepare a platinum electrode by charging it with hydrogen gas by electrolysis of sulphuric acid (for approx. 3-5 minutes).

1. Combine the hydrogen electrode prepared in this way with four different half cells, each containing a different metal, one after the other.
2. Measure the occurring voltage of each galvanic cell.
3. Note the voltages with magnitude and sign.
4. Arrange the metals in a voltage series according to the measured voltages - from the highest to the lowest potential.

## Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense Voltage - Sensor for measuring electrical voltage $\pm$ 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	2
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	Block with 8 holes, d = 40 mm	37682-00	1
8	Coverage f.cell-meas.bloc,8 piec.	37683-00	1
9	Silver foil, 150 x150 x 0.1 mm, 25g	31839-04	1
10	Graphite electrode,d=5,l=150,6pc	44510-00	1
11	Electrode platinum,short	45207-00	1
12	Beaker, Borosilicate, tall form, 50 ml	46025-00	5
13	Dropping bottle,plastic,50ml	33920-00	1
14	Flat battery, 4.5 V	07496-01	1
15	Copper-II sulphate,cryst. 250 g	30126-25	1
16	Potassium nitrate 250 g	30106-25	1
17	Zinc sulphate 7-hydr. 250 g	30249-25	1
18	Silver nitrate, cryst. 25 g	30222-04	1
19	Sulphuric acid,0.5M 1000 ml	48462-70	1
20	Water, demineralized, pure, 10000 ml	CHE-882041145	1
21	Chromatographic paper 100 stripes	32972-00	1
22	Protecting glasses, clear glass	39316-00	1

## Additional material

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

## Preparation (1/2)

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**The solutions can be produced for everyone to save chemicals!**

- **Copper sulphate solution (1 mol/l):** Add 12,5 g Copper sulphate to 25 ml distilled water. Mix well and fill up to 50 ml with distilled water.
- **Lead nitrate solution (1 mol/l):** Add 16,5 g Lead nitrate to 25 ml distilled water. Mix well and fill up to 50 ml with distilled water.

**Optional production of sulphuric acid (0,5 mol/l):** Pour into a beaker 10 ml distilled water. Pipette 1,4 ml of 96% sulphuric acid and fill up to 50 ml with distilled water.

## Preparation (2/2)

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The solutions can be produced for everyone to save chemicals!

- **Zinc sulphate solution** (1 mol/l): Add 14,4 g Zinc sulphate to 25 ml distilled water. Mix well and fill up to 50 ml with distilled water.
- **Silver nitrate solution** (1 mol/l): Add 8,5 g Silver nitrate to 25 ml distilled water. Mix well and fill up to 50 ml with distilled water.
- **Potassium nitrate solution** (1 mol/l): Add 5,1 g Potassium nitrate to 25 ml distilled water. Mix well and fill up to 50 ml with distilled water.

**Hint:** A silver electrode is not included in the standard range and must therefore be provided separately (see Additional material).

## Setup (1/4)

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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 (2/4)

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Moisten four salt bridges (three short, one long) 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).

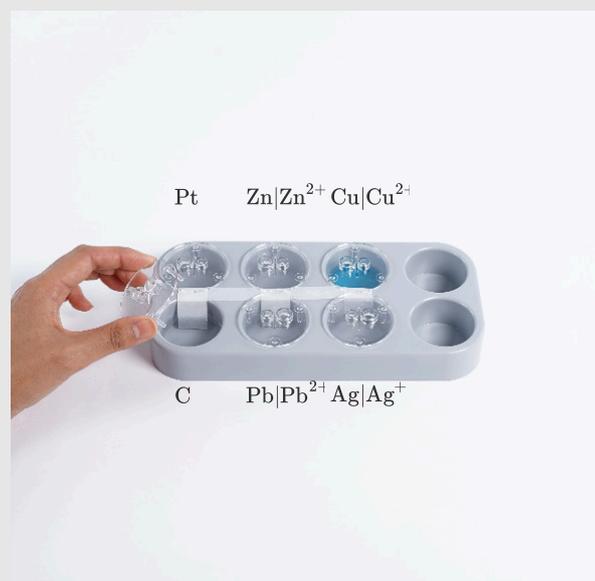


## Setup (3/4)

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Fill measuring cells 1 and 2 with the diluted sulphuric acid and cells 3 to 6 with the corresponding metal salt solutions (see illustration).

Place a measuring cell cover on each measuring cell.



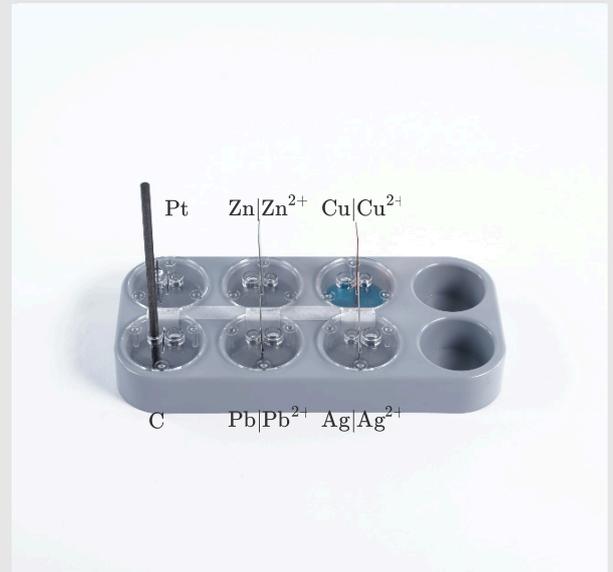
## Structure (4/4)

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Take a look at the electrodes: If the metal has oxidised due to storage, use a piece of sandpaper to remove the oxide layer.

Then insert a platinum electrode into measuring cell 1, a carbon electrode into cell 2 and the specified metal electrodes into cells 3 to 6: platinum, zinc, copper, silver and carbon (graphite).

**Note:** A silver electrode is not included in the standard range and must therefore be provided separately.



## Realisation (1/4)

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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.



**Devices**

- Apple iPad13,16 - Accelerometer (internal)
- V 4885 - Voltage

**Measurement channel**

**Configuration**

V 4885 - Voltage

**Measurement channel**

Voltage

● U [V]

Calculated channels

U 0,00 V

## Realisation (2/4)

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### Note the polarity below!

The platinum electrode in cell 1 is the negative pole (blue), the carbon electrode in cell 2 is the positive pole (red). *Make sure that the colours are assigned correctly: blue (negative pole) always to blue/black, red (positive pole) always to red.*

1. Take two cables and attach an alligator clip to each end.
2. Connect one end of the cables to the electrodes and the other end to a DC voltage source (battery 4, 5 V).



## Realisation (3/4)

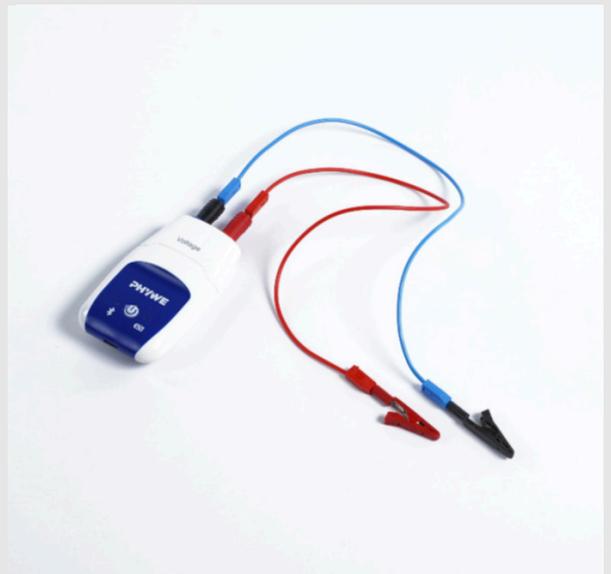
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Electrolyse the sulphuric acid between the two electrodes for about 3 to 5 minutes.

After this time, disconnect the connections to the voltage source, replace the crocodile clips with reducing plugs and connect the Cobra SMARTsense Voltage (see illustration).

*Connect the platinum electrode to the negative pole (blue) and the carbon electrode to the positive pole (red)!*

Read the voltage displayed in the measureAPP.



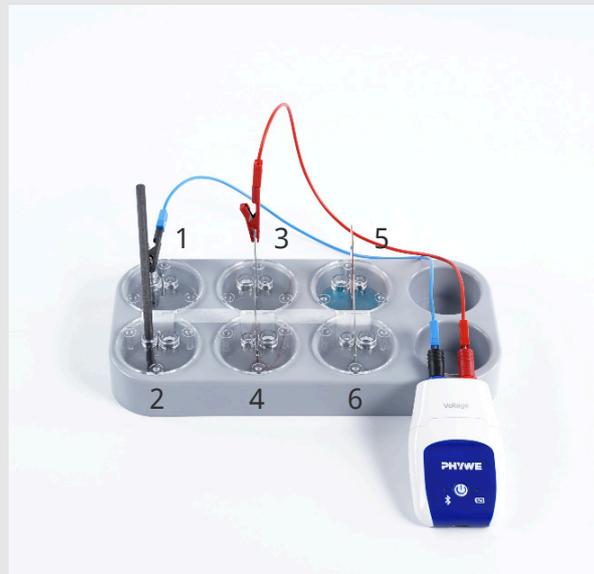
## Procedure (4/4)

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Some measurements can now be carried out with the simplified standard hydrogen electrode.

Now connect half cells 3 to 6 to the positive terminal of the Cobra SMARTsense Voltage one after the other.

Measure the corresponding voltages using the measureAPP.



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## Report



## Task 1

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What is the standard potential of a metal?

- There is no standard potential for metals, only for non-metals.
- The standard potential of a metal is nothing other than the potential difference between this metal and a standard hydrogen electrode.
- The standard potential of a metal is always specified with the value 2.
- The standard potential of a metal is nothing other than the potential difference between this metal and a non-metal.

✓ Check

## Task 2

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Against which metals does the hydrogen electrode form the positive or negative pole?

- Positive pole: copper, silver, lead and zinc, negative pole: —
- Positive pole: —, Negative pole: copper, silver, lead and zinc
- Positive pole: copper and silver, negative pole: lead and zinc
- Negative pole: copper and silver, positive pole: lead and zinc

✓ Check

## Task 3

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Why was 0.5 molar sulphuric acid used for the hydrogen electrode in this experiment instead of the usual hydrochloric acid?

- The electrolysis of hydrochloric acid can produce dangerous chlorine gas.
- Sulphuric acid is cheaper than hydrochloric acid.
- Sulphuric acid gives a more stable redox potential than hydrochloric acid.
- Sulphuric acid enables better electron transfer.

 Check

Slide	Score/Total
Slide 28: Standard potential	0/1
Slide 29: Hydrogen electrode Metals	0/1
Slide 30: Hydrogen electrode	0/1

Total amount  0/3 Solutions Repeat