# Nonmetal galvanic cells with Cobra SMARTsense


In this experiment, the pupils learn that galvanic elements can also be produced from non-metals.

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/68cbdd892033c10002a9d86e

# Teacher information

## Application


Experimental setup

The discovery and further development of so-called galvanic elements, better known as batteries, is of great importance to our standard of living today. They enable the mobile power supply of a wide range of electrical devices.

Non-metals, like metals, also develop different **Solution pressures** and thus potential if they are used in suitable solvents. **Redox systems** form. A potential difference between a hydrogen and an oxygen half-cell is technically utilised in fuel cells, for example, to generate environmentally friendly electricity.



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## Other teacher information (1/10)

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**Prior knowledge**

Students should have worked with galvanic elements in theory and practice.

**Principle**

Just like metals, non-metals also develop different solution pressures and thus different potentials as soon as they can form redox systems in corresponding solvents.

## Other teacher information (2/10)

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**Learning objective**

So far, the students have analysed conventional galvanic elements in more detail. In this experiment, the students learn that galvanic elements can also be produced from non-metals.

**Tasks**

The students should produce a simplified standard hydrogen electrode as well as oxygen, chlorine, bromine and iodine half-cells. These half-cells should then be connected together to form galvanic cells whose standard potentials are to be measured.



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## Other teacher information (3/10)

If, for example, a standard hydrogen electrode is connected to a half cell in which the redox system

$$2\,Cl^- \rightarrow Cl_2 + 2\,e^-$$

a direct electrical voltage can be measured. There is also a potential difference between a hydrogen half-cell and an oxygen half-cell, which is used to generate electricity in so-called fuel cells, for example.

As solid electrodes cannot be produced from non-metals such as oxygen or chlorine, a tried and tested trick is used - as with the hydrogen electrode: a conductive carrier material, e.g. graphite carbon, is used and coated with the respective non-metal.

In the following experiments, this coating is achieved by electrolysis, which precedes the actual potential measurements.

## Other teacher information (4/10)

During the electrolysis of sulphuric acid, hydrogen gas is produced at the negative pole (cathode). In the process, oxonium ions are reduced by accepting electrons:

$$4\,H_3O^+ + 4\,e^- \rightarrow 4\,H_2O + 2\,H_2 \uparrow$$

The resulting hydrogen forms a thin, invisible and largely closed layer on the surface of the platinum electrode. This practically creates a simplified hydrogen electrode.

At the positive pole (anode), water molecules are oxidised by removing electrons. This produces oxygen gas and again oxonium ions:

$$6\,H_2O \rightarrow 4\,H_3O^+ + 4\,e^- + O_2 \uparrow$$



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## Other teacher information (5/10)

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The oxygen produced during electrolysis coats the carbon electrode in a thin layer, turning it into an oxygen electrode. Once electrolysis is complete, the result is a galvanic hydrogen-oxygen cell - in other words, a simple fuel cell.

If the two electrodes of this cell are connected via a wire so that an electric current can flow, the following processes take place:

**Hydrogen electrode (anode)**

$$2\,H_2 + 4\,H_2O \rightarrow 4\,H_3O^+ + 4\,e^-$$

Hydronium ions are formed again through the oxidation of hydrogen. The electrons released in the process flow via the external circuit to the oxygen electrode. Due to the outflow of electrons, the hydrogen half cell is the **Anode** and forms in the galvanic cell the **Negative pole**.

## Other teacher information (6/10)

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**Oxygen electrode (cathode)**

$$O_2 + 4\,H_3O^+ + 4\,e^- \rightarrow 6\,H_2O$$

Oxygen and oxonium ions are reduced to water by the addition of electrons. The oxygen electrode thus acts as a **Cathode** of the galvanic cell.

**Interpretation**

At the hydrogen electrode, identical reactions take place both during electrolysis and during current output as described above.

At the carbon electrode of cells 3, 4 and 5, on the other hand, the electrolysis process produces **Chloride, bromide or iodide ions** through electron removal to the corresponding **Halogens** oxidised.



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## Other teacher information (7/10)

During the electrolysis of the potassium iodide solution, for example, iodide ions are oxidised at the carbon electrode:

$$2\,I^- \rightarrow I_2 + 2\,e^-$$

The resulting iodine is partially deposited on the electrode or dissolves in the water. This creates an iodine electrode.

If this is connected to a hydrogen electrode, a galvanic cell is created. The iodine is reduced again during the current output:

$$2\,H^+ \rightarrow H_2 + 2\,e^-$$

The resulting voltage is the potential difference between the halogen electrode and the hydrogen electrode.

## Other teacher information (8/10)

The standard potentials of the halogen are

$$Cl_2|2\,Cl^- \qquad E^0 = +1,358\ V$$

$$Br_2|2\,Br^- \qquad E^0 = +1,065\ V$$

$$I_2|2\,I^- \qquad E^0 = +0,535\ V$$

These decrease from chlorine to iodine. These differences can be seen in the measured voltage compared to the hydrogen electrode.



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## Other teacher information (9/10)

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

- **Potassium chloride solution** $(1\,\mathrm{mol/l})$**:** Add $37,3\,\mathrm{g}$ Potassium chloride to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.
- **Potassium bromide solution** $(1\,\mathrm{mol/l})$**:** Add $59,5\,\mathrm{g}$ Potassium bromide to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.

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

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

## Other teacher information (10/10)

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

- **Potassium iodide solution** $(1\,\mathrm{mol/l})$**:** Add $83\,\mathrm{g}$ Potassium iodide to $250\,\mathrm{ml}$ distilled water. Mix well and fill up to $500\,\mathrm{ml}$ with distilled water.
- **Potassium nitrate solution** $(1\,\mathrm{mol/l})$**:** Add $50,5\,\mathrm{g}$ 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.



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## Safety instructions

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- The general instructions for safe experimentation in science lessons apply to this experiment. For H and P phrases, please refer to the safety data sheet of the respective chemical.
- All persons in the room must wear safety goggles during the experiment!
- Potassium bromide, potassium chloride solutions of concentration $c = 1,0\,\mathrm{mol/l}$ and sulphuric acid solutions of the concentration $c = 0,5\,\mathrm{mol/l}$ have an irritant effect.
- Potassium iodide solutions of the concentration $c = 1,0\,\mathrm{mol/l}$ are harmful if swallowed, whereby sensitisation through skin contact is possible.
- **Caution:** During electrolysis, small amounts of halogens are produced in molecular form. These should largely dissolve in the water, but for safety reasons, work should be carried out in a fume cupboard or well-ventilated area!

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# Student information



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## Motivation

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The discovery of galvanic elements, i.e. batteries, was an important step for modern technology. They enable the mobile power supply of many devices that have become an integral part of our everyday lives.

This experiment is about how non-metals, like metals, can also develop different electrical potentials. You will investigate how this can be used to create galvanic cells with non-metals and learn about another important principle of chemical energy conversion.

## Tasks

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How do non-metals fit into the voltage series?

1. Produce a simplified standard hydrogen electrode.
2. Produce oxygen, chlorine, bromine and iodine half cells.
3. Build galvanic cells from these half cells.
4. Measure the standard potentials of the galvanic cells formed.



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# Equipment

| Position | Material | Item No. | Quantity |
|---|---|---|---|
| 1 | Cobra SMARTsense Voltage - Sensor for measuring electrical voltage ± 30 V (Bluetooth + USB) | 12901-02 | 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 | 2 |
| 6 | Block with 8 holes, d = 40 mm | 37682-00 | 1 |
| 7 | Coverage f.cell-meas.bloc,8 piec. | 37683-00 | 1 |
| 8 | Graphite electrode,d=5,l=150,6pc | 44510-00 | 1 |
| 9 | Electrode platinum,short | 45207-00 | 1 |
| 10 | Beaker, Borosilicate, tall form, 50 ml | 46025-00 | 4 |
| 11 | Dropping bottle,plastic,50ml | 33920-00 | 1 |
| 12 | Flat battery, 4.5 V | 07496-01 | 1 |
| 13 | Potassium chloride 250 g | 30098-25 | 1 |
| 14 | Potassium bromide, 100 g | 30258-10 | 1 |
| 15 | Potassium iodide 100 g | 30104-10 | 1 |
| 16 | | CHE-881204931 | 1 |
| 17 | Water, demineralized, pure, 10000 ml | CHE-882041145 | 1 |
| 18 | Sulphuric acid,0.5M 1000 ml | 48462-70 | 1 |
| 19 | Chromatographic paper 100 stripes | 32972-00 | 1 |
| 20 | Protecting glasses, clear glass | 39316-00 | 1 |



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## Additional material

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

## Setup (1/5)

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To measure with the **Cobra SMARTsense** sensors, the **PHYWE measureAPP** is required. The app can be downloaded free of charge from the respective app store (QR codes below). Please check that **Bluetooth is enabled** on your device (smartphone, tablet, desktop PC) before starting the app.

iOS

Android

Windows



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## Setup (2/5)

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**Produce the required solutions:**

- **Potassium chloride solution** $(1\ \mathrm{mol/l})$: Add $3,73\ \mathrm{g}$ Potassium chloride to $25\ \mathrm{ml}$ distilled water. Mix well and fill up to $50\ \mathrm{ml}$ with distilled water.
- **Potassium bromide solution** $(1\ \mathrm{mol/l})$: Add $5,95\ \mathrm{g}$ Potassium bromide to $25\ \mathrm{ml}$ distilled water. Mix well and fill up to $50\ \mathrm{ml}$ with distilled water.

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

## Setup (3/5)

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**Produce the required solutions:**

- **Potassium iodide solution** $(1\ \mathrm{mol/l})$: Add $8,3\ \mathrm{g}$ Potassium iodide 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 $5,05\ \mathrm{g}$ 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 (4/5)

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 six measuring cells in the measuring cell block (see figure).

## Setup (5/5)

Fill measuring cells 1 and 2 with sulphuric acid $(c = 0,5\,\mathrm{mol/l})$cell 3 with potassium chloride solution, measuring cell 4 with potassium bromide solution and measuring cell 5 with potassium iodide solution (see figure).

Place a measuring cell cover on each measuring cell.




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# Realisation (1/4)

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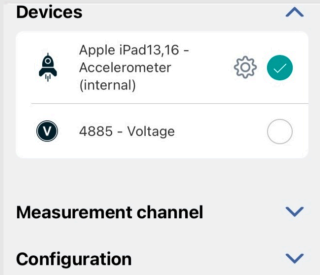
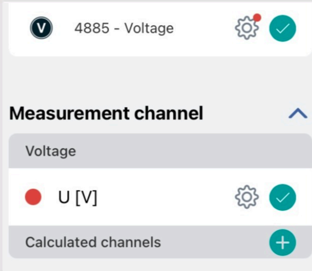
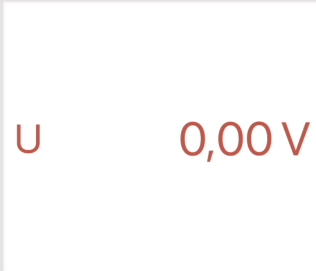
- Start the measureAPP on a mobile device.
- Press the start button on the sensor for approx. 3 seconds.
- Connect the sensor by tapping ◯ next to the description of the sensor in the measureAPP.
- Set the measured value display by tapping 0.0 above the diagram.


# Realisation (2/4)

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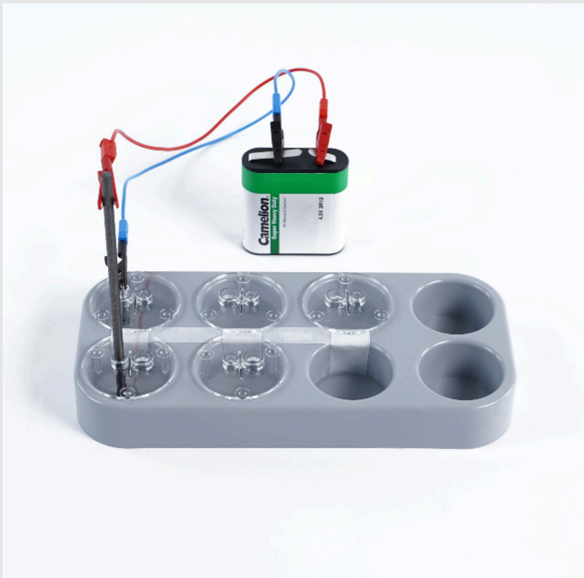
1. insert the platinum electrode into measuring cell 1 and the carbon electrode into measuring cell 2.

2. take two cables and attach a crocodile clip to each end.

**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.*

3. connect one end of the cables to the electrodes and the other end to a DC voltage source (battery 4.5 V)



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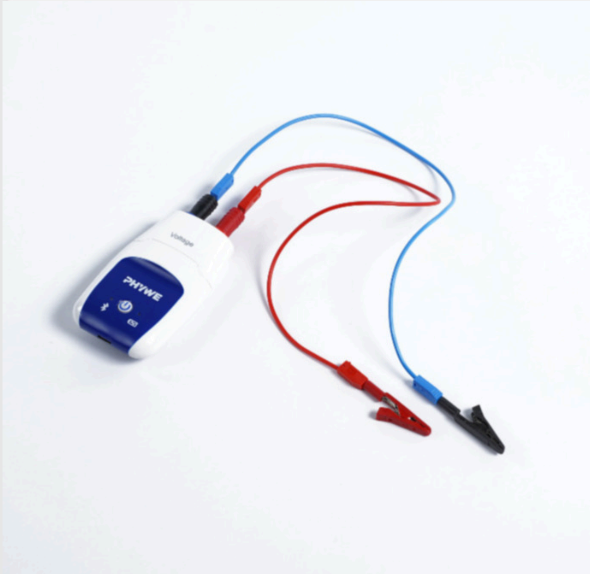
## Realisation (3/4)

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

After this time, disconnect the connections to the voltage source and quickly connect the Cobra SMARTsense Voltage to the galvanic cell.

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

Read the displayed voltage. Take a note of your observations: Are there gas bubbles forming during electrolysis?




## Procedure (4/4)

Connect the hydrogen electrode (half cell 1) to the negative terminal and half cell 3 to the positive terminal of the DC voltage source and electrolyse for 3-5 minutes.

Then disconnect the voltage source and measure the voltage between half cells 1 and 3 again.

Repeat this with half cells 4 and 5: First electrolyse, then measure the voltage across the hydrogen electrode.

Take a note of your observations: Are there gas bubbles forming during electrolysis? How do the voltages change between the different experiments?

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# Report

## Task 1

Between which redox systems can an electrical voltage be measured?

- No voltage can be measured between the redox systems of the halogens.
- A voltage can be measured between the redox systems of the halogens; it decreases from chlorine to iodine.
- A voltage can be measured between the redox systems of the halogens; it increases from chlorine to iodine.
- The voltage is the same for all halogens.

Check



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## Task 2

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Select the correct statements.

- [ ] Galvanic elements can also be produced from non-metals.
- [ ] There is a potential difference between a hydrogen half-cell and an oxygen half-cell, which is used to generate electricity in so-called fuel cells, for example.
- [ ] Just like metals, non-metals also develop different solution pressures and thus different potentials as soon as they can form redox systems in corresponding solvents.

Check

## Task 3

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Which statements about the redox reaction are correct?

- [ ] The partner that accepts electrons is called the oxidation partner.
- [ ] In the redox reaction, electrons are transferred from one reaction partner to the other.
- [ ] The reduction partner is reduced.
- [ ] The partner that releases electrons is referred to as the reducer.

Check



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| Slide | Score / Total |
| --- | --- |
| Slide 29: Redox systems | **0/1** |
| Slide 30: Non-metals Metals | **0/3** |
| Slide 31: Redox reaction | **0/3** |

**Total amount** **0 / 7**

Solutions Repeat



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