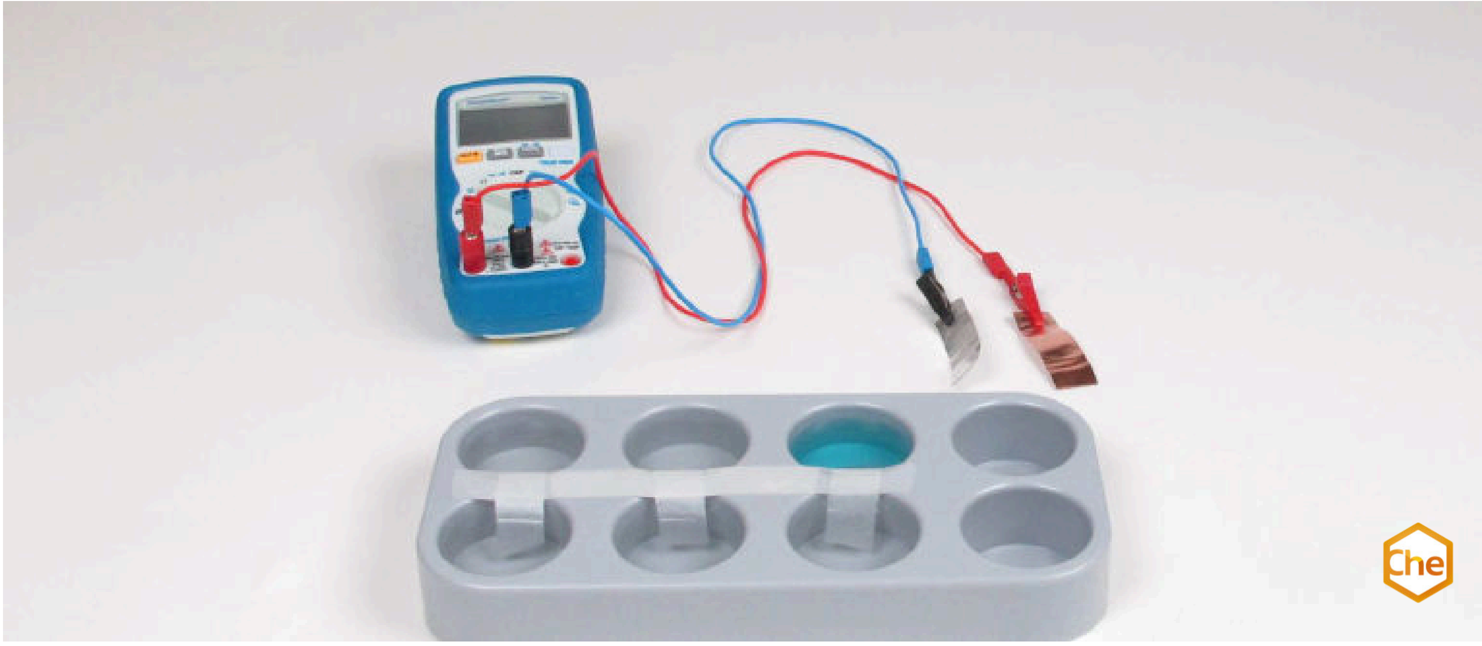
Preparation of a simplified standard hydrogen electrode andmeasurement of some standard potentials



The students will make a simplified standard hydrogen electrode during the experiment. In addition, the term "standard potential" will be 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:

http://localhost:1337/c/6353d1266ec4f300037c60f5

Teacher information

Application

Experimental setup

DC voltages of different levels arise between different metals as soon as they are combined in galvanic cells. These voltages are the quantitative expression of the potential differences between the respective interconnected half cells. The differences between the potentials of different metals can be measured when they are combined in galvanic cells. This now makes it possible to assign a relative potential value to each metal (and also to other redox pairs) as soon as it is connected to an always identical reference electrode to form a galvanic cell.

The so-called "standard hydrogen electrode" was determined as such a reference electrode.

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Other teacher information (1/7)

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Prior knowledge

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

Principle

Using the standard potentials, one can easily calculate the potential differences or the voltages between all metal combinations according to the equation:

Other teacher information (2/7)

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Learning objective

Students will make a simplified standard hydrogen electrode during the experiment so that an understanding of its working principle and construction is deepened. In addition, the term "standard potential" will be further discussed.

Tasks

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

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Other teacher information (3/7)

Other information (1/5)

In experiment 7400700 it was observed that DC voltages of different magnitudes 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 potentials of the metals are based on redox processes.

The greater the tendency of a metal to dissolve, the further to the right lies the equilibrium of such a redox process. However, since it is not possible to measure this solution tendency or the potential of a metal in a half-cell on its own, it is not possible to assign it a specific order of magnitude without further ado. However, as experiment P7400700 showed, the differences between potentials of different metals are measurable when they are combined into galvanic cells.

Other teacher information (4/7)

Other information (2/5)

This now makes it possible to assign a relative potential value to each metal (and also to other redox pairs) as soon as it is connected to an always identical reference electrode to form a galvanic cell. The so-called "standard hydrogen electrode" was determined as such a reference electrode by agreement. It has the following structure:

A platinum sheet electrolytically coated with finest platinum particles (= platinum ear) is immersed as an electrode in 1 molar hydrochloric acid. A fine-bubble stream of hydrogen is allowed to bubble over this electrode under a pressure of 1013 mbar (= 1013 hectopascals). The temperature should be 25 °C. Due to its catalytic effect, the platinum sheet is covered with a closed layer of atomic hydrogen over the entire surface, so that the platinum electrode practically becomes a hydrogen electrode. The redox process can then take place at such an electrode.

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Other teacher information (5/7)

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Other information (3/5)

If one connects such a standard hydrogen electrode as a half cell with a half cell of a metal to form a galvanic cell, one can measure a voltage as between two metallic half cells. The potential of the standard hydrogen electrode is now set to the value ± 0, and the voltage measured at such a cell is determined as the standard potential of the respective metal used. The standard potential of a metal is thus nothing other than the potential difference between this metal and a standard hydrogen electrode.

Since it is difficult to manufacture a standard hydrogen electrode, a simplified version is used for the following experiments, which can be manufactured with little means and which leads to measured values that are very close to the literature values.

The potential differences of the redox pairs to the standard hydrogen electrode (redox pair) are called STANDARD POTENTIALS, as already mentioned above. If one includes the potential of the hydrogen with the set value ±0 in the obtained series of measurements, the following series results:

Other teacher information (6/7)

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Other information (4/5)

Material	Standard Potential **E0**	Redox system
Zinc (Zn)	- 0.75 to - 0.76 V	**Zn2+ + 2e-**
Lead (Pb)	- 0.12 to - 0.13 V	**Pb2+ + 2e-**
Hydrogen (H)	± 0 V	**H+ + e-**
Copper (Cu)	+ 0.34 to + 0.35 V	**Cu2+ + 2e-**
Silver (Ag)	+ 0.79 to + 0.80 V	**Ag+ + e-**

The metals thus arranged according to standard potentials result in the so-called ELECTRICAL VOLTAGE SERIES OF METALS. The following table contains the exact values of the standard potentials of all important metals.

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Other teacher information (7/7)

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Other information (5/5)

Metall	Redoxystem	Standardpotenzial ($E^0/V-$)
Cäsium (Cs)	$Cs^+ + e^-$	-2,92
Kalium (K)	$K^+ + e^-$	-2,924
Calcium (Ca)	$Ca^{2+} + 2\,e^-$	-2,868
Natrium (Na)	$Na^+ + e^-$	-2,71
Magnesium (Mg)	$Mg^{2+} + 2\,e^-$	-2,375
Aluminium (Al)	$Al^{3+} + 3\,e^-$	-1,662
Zink (Zn)	$Zn^{2+} + 2\,e^-$	-0,7628
Chrom (Cr)	$Cr^{3+} + 3\,e^-$	-0,744
Eisen (Fe)	$Fe^{2+} + 2\,e^-$	-0,409
Cobalt (Co)	$Co^{2+} + 2\,e^-$	-0,28
Nickel (Ni)	$Ni^{2+} + 2\,e^-$	-0,23
Zinn (Sn)	$Sn^{2+} + 2\,e^-$	-0,136
Blei (Pb)	$Pb^{2+} + 2\,e^-$	-0,126
Wasserstoff (H)	$H^+ + e^-$	±0
Kupfer (Cu)	$Cu^{2+} + 2\,e^-$	+0,3402
Silber (Ag)	$Ag^+ + e^-$	+0,7996
Platin (Pt)	$Pt^{2+} + 2\,e^-$	+1,20
Gold (Au)	$Au^{3+} + 3\,e^-$	+1,42

Please click on the button for a larger view of the table:

Safety instructions

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- Wear protective goggles and gloves.
- 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 concentration c = 1.0 mol/l and sulphuric acid solutions of concentration c = 0.5 mol/l have an irritant effect.
- 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

Motivation

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Experimental setup

The discovery and further development of the so-called galvanic elements, better known as batteries, has a particularly great significance for people. Among other things, this makes the mobile power supply of a wide variety of electrical devices possible, which has a significant impact on our standard of living today.

If we use different metals in the galvanic elements, we can measure different differences between the potentials.

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Tasks

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200 µF, 20 kHz, −20°C…760°C	07122-00	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	2
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, 25 g	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

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Preparation (1/2)

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Producing the required solutions

- **Sulphuric acid (0.5 mol/l):** Pour 100 ml of distilled water into a beaker. Add 13.8 ml of 96 % sulphuric acid and fill up to 500 ml with distilled water.
- **Copper sulphate solution (1 mol/l):** Add 79.5 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 166 g lead nitrate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.

Preparation (2/2)

PHYWE

Producing the required solutions

- **Zinc sulphate solution 1 mol/l):** Add 80.5 g zinc sulphate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.
- **Silver nitrate solution (0.1 mol/l)**: Add 8.49 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 55.5 g potassium nitrate to 250 ml distilled water. Mix well and fill up to 500 ml with distilled water.

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Set-up

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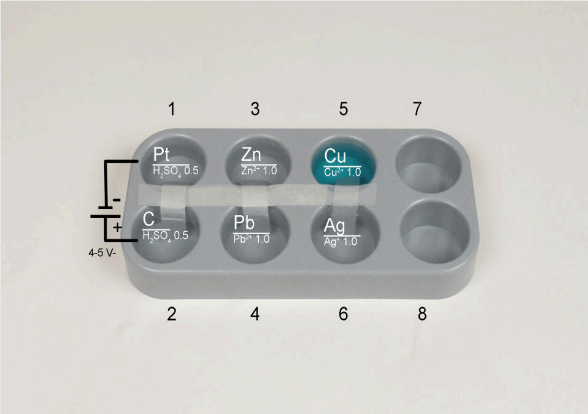
Distribute the sulphuric acid and the other solutions into the measuring cells 1 to 6 (fig. right).

Connect all these measuring cells to each other with current keys made of soaked filter paper strips (potassium nitrate solution). First place current keys between the measuring cell pairs 1/2, ¾ and 5/6, and then connect them to each other by a soaked filter paper strip along the centre line of the measuring cell block.

Put lids on all 6 measuring cells. 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.



Distribute the solutions in the measuring cells

Procedure

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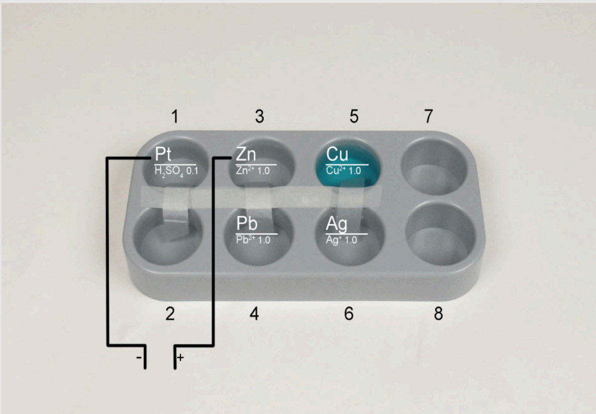
Connect the platinum electrode to the negative pole of a flat battery (4.5 V) or another DC voltage source, and the carbon electrode to the positive pole. The electrolysis that now begins produces hydrogen at the cathode and oxygen at the anode.

After an electrolysis time of 2 to 3 minutes, the platinum electrode is covered with an invisible hydrogen layer, which practically creates a simplified standard hydrogen electrode with which you can carry out some measurements. Now connect this hydrogen electrode (half cell 1) to the ground socket of the measuring instrument (setting 2 V-) (fig. right) and the volt socket to half cells 3 to 6 in succession.



Connect this hydrogen electrode to the ground socket of the measuring instrument.

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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 that metal and a standard hydrogen electrode.
- ○ The standard potential of a metal is always indicated with the value 2.
- ○ The standard potential of a metal is nothing other than the potential difference between that metal and a non-metal.

Check

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Task 2

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

- ○ Positive pole: - Minus pole: copper, silver, lead, zinc, potassium
- ○ Minus pole: copper, silver Positive pole: lead, zinc, potassium
- ○ Positive pole: copper, silver Minus pole: lead, zinc, potassium
- ○ Positive pole: copper, silver, lead, zinc, potassium Minus pole: -

Check

Task 3

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Why was hydrochloric acid not used to build up the hydrogen electrode in this experiment, as is usually the case, but 0.5 molar sulphuric acid?

- ○ For safety reasons. The electrolysis of the sulphuric acid produces chlorine, which has a health-promoting effect.
- ○ For reasons of cost. Hydrochloric acid is very expensive.
- ○ For safety reasons. No chlorine is produced during the electrolysis of the sulphuric acid.

Check

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Slide	Score / Total
Slide 20: Standard potential	0/1
Slide 21: Hydrogen electrode Metals	0/1
Slide 22: Hydrogen electrode	0/1

Total 0 / 3

Solutions Repeat

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