Electrochemical series of metals
(Using the electrochemistry demonstration unit)

Aims of the experiment

- To determine the electrochemical series of metals experimentally.
- To link various half-cells to form electrical elements.
- To learn about redox reactions.
- To determine reducing and oxidising agents.

Principles

Redox reactions form the basis of electrochemistry. These are reactions in which electrons are released by one reaction partner and taken on by another reaction partner. The name "redox" comprises the individual reactions which take place simultaneously, reduction and oxidation. Reduction describes the reaction in which a reaction partner takes on electrons. With oxidation, on the other hand, electrons are released. Substances which oxidise other substances are referred to as oxidising agents. Substances which reduce others are called reducing agents.

Not all substances have the same tendency to release or to take on electrons because they have differing tendencies for dissolution or deposition. If a metal is immersed in a solution of one of its salts, a potential is set up based on its tendency for dissolution or deposition. In the case of metals with a great tendency to release electrons, the metal will acquire a negative charge owing to the valency electrons that remain, while the solution will acquire a positive charge. This applies to zinc and iron, for example. These metals easily oxidise and are referred to as non-noble. In the case of metals which have a greater tendency for deposition, the situation is reversed. The metal acquires a positive charge because the metal ions from the solution are deposited on it. These metals do not easily oxidise and are referred to as noble. These include metals such as silver and copper.

If a metal is immersed in a solution of one of its salts and such a potential is set up, this structure is referred to as a half-cell. The potential of a half-cell alone is not measurable. If two half-cells are conductively connected with each other, an electrochemical cell is produced. A voltage is then measurable, which represents the potential difference between the two half-cells. The greater this difference, the more the two metals differ in their tendency to dissolve or deposit. In addition, it can be determined experimentally which metal forms the cathode and which forms the anode. Half-cells can be connected conductively with one another, for example when they are connected via a membrane such that electrons can diffuse from one half-cell to another.

Fig. 1: Setting up the experiment.

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If various half-cells are combined, they can be arranged in order on the basis of the values obtained for the potential differences. The so-called electrochemical series of metals can be determined experimentally. Here, the least noble metal will always form the anode in all combinations. The noblest metal, on the other hand, will always form the cathode in all experiments. The remaining metals can then be placed in order on the basis of the potential differences compared with these two metals.

With the help of the electrochemical series of metals, conclusions can be drawn on the process of redox reactions. Predictions can thus be made about which reactions will take place voluntarily and which will need a voltage to be applied to force the reaction.

In this experiment, the electrochemical series of metals will be determined experimentally using the example of copper, silver, iron and zinc. Lead and nickel can also be classified. To achieve this, the metals are combined successively with one another in an electrochemical cell. The electrochemical series can then be determined on the basis of the voltages measured and the polarity in each case.

Risk assessment

Avoid by all means skin contact with zinc sulfate heptahydrate, silver nitrate and hydrochloric acid.

Lead sulfate and nickel chloride are toxic and carcinogenic. Decide from case to case whether the use justifies the risks.

Lead (II) nitrate	
Signal word: **Hazard**	**Hazard statements** H272 May intensify fire; oxidizer H360Df May damage the unborn child. Suspected of damaging fertility. H332 Harmful if inhaled. H302 Harmful if swallowed. H318 Causes serious eye damage. H373 May cause damage to organs through prolonged or repeated exposure. H410 Very toxic to aquatic life with long-lasting effects. **Precautionary statements** P201 Obtain special instructions before use. P273 Avoid release to the environment. P305+P351+P338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. P308+P313 If exposed or concerned: Get medical advice/attention.
Iron(II) sulfate heptahydrate	
Signal word: **Caution**	**Hazard statements** H302 Harmful if swallowed. H319 Causes serious eye damage. H315 Causes skin irritation. **Precautionary statements** **P305+P351+P338** If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing P302+P352 If on skin: Wash with soap and water
Copper(II) sulfate	
Signal word: **Caution**	**Hazard statements** H302 Harmful if swallowed. H315 Causes skin irritation. H319 Causes serious eye irritation. H302 Harmful if swallowed. H410 Very toxic to aquatic life with long-lasting effects. **Precautionary statements** P273 Avoid release to the environment. P305+P351+P338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing P302+P352 If on skin: Wash with soap and water
Silver nitrate	
Signal word: **Hazard**	**Hazard statements** H272 May intensify fire; oxidizer H314 Causes severe skin burns and eye damage. H410 Very toxic to aquatic life with long-lasting effects. **Precautionary statements** P273 Avoid release to the environment. P280 If exposed or concerned: Get medical advice/attention. P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting. P305+P351+P338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing P309+P311 If exposed or you feel unwell: Call a poison centre or doctor/physician.
Zinc sulfate heptahydrate	
Signal word: **Hazard**	**Hazard statements** H302 Harmful if swallowed. H318 Causes serious eye damage. H410 Very toxic to aquatic life with long-lasting effects. **Precautionary statements** P273 Avoid release to the environment. P280 Wear protective gloves/protective clothing/eye protection/face protection. P305+P351+P338 If in eyes: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing
Nickel(II) chloride	

Signal word: Hazard

Hazard statements

H350i May cause cancer by inhalation.
H341 Suspected of causing genetic defects.
H360D May damage the unborn child.
H301 Toxic if swallowed.
H331 Toxic if inhaled.
H373 Causes damage to organs through prolonged or repeated exposure by inhalation.
H315 Causes skin irritation.
H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled.
H317 May cause allergic skin reactions.
H410 Very toxic to aquatic life with long-lasting effects.

Precautionary statements

P201 Obtain special instructions before use .
P273 Avoid release to the environment.
P308+P313 If exposed or concerned: Get medical advice/attention.
P304+P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P302+P352 IF ON SKIN: Wash with soap and water.
P309 + P310 IF exposed or you feel unwell:: Immediately call a POISON CENTER or doctor/ physician.

Equipment and chemicals

1	Electrochemistry demonstration unit, CPS	664 4071
1	Electrochemistry accessories set	664 401
1	Panel frame C50, two-level, for CPS	666 425
1	Table for electrochemistry, CPS	666 472
4	Beaker, DURAN, 150 mL, tall	602 032
1	Compact balance 200 g : 0.01 g	667 7977
1	Measuring cylinder 100 mL, plastic base	665 754
1	Copper(II) sulfate pentahydrate, 100 g	672 9600
1	Zinc sulfate heptahydrate, 250 g	675 5410
1	Silver nitrate, 25 g	674 8610
1	*Lead nitrate solution, 500 mL*	*670 9650*
1	Iron(II) sulfate heptahydrate, 250 g	671 9110
1	Nickel(II) sulfate, 100 g	673 9000
4	Glass rod, from set	665 212ET10

Set-up and preparation of the experiment

Set-up of the apparatus

1. Insert the electrochemistry demonstration unit into the upper panel frame and supply with electrical power.

2. Place the table for electrochemistry, CPS into the frame below (see Fig. 1).

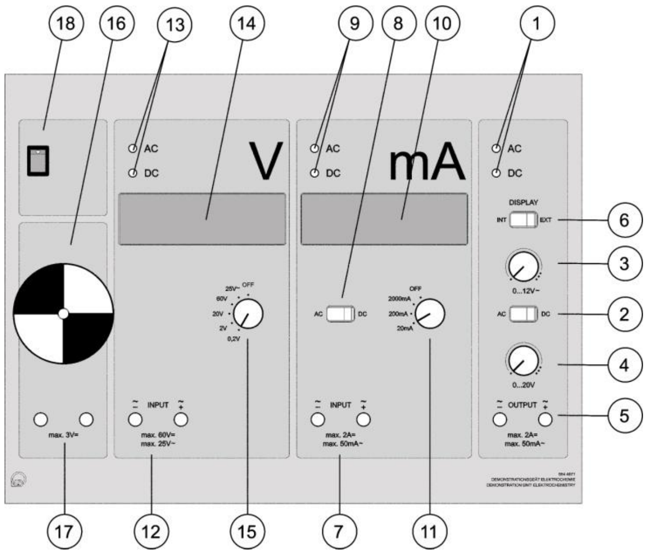

Fig. 2 Electrochemistry demonstration unit

Preparing the solutions

1. 1 M solutions will be prepared.
2. For this, the quantities of iron(II) sulfate heptahydrate, copper sulfate pentahydrate, silver nitrate, zinc sulfate heptahydrate and possibly nickel sulfate to be weighed out are calculated. The quantity required to be weighed is for 100 mL in each case.
3. The molar masses of the substances are required for the calculation.

$M(FeSO_4 * 7H_2O)$ = 278.00 g/mol
$M(CuSO_4 * 5H_2O))$ = 249.69 g/mol
$M(AgNO_3)$ = 169.87 g/mol
$M(ZnSO_4 * 7H_2O)$ = 287.53 g/mol
($M(NiSO_4)$ = 154.75 g/mol)

The calculation for 100 mL of a 1 M solution is performed as follows:

$$m = c \cdot V \cdot M$$

From this, the following weights are obtained:

$m(FeSO_4 * 7H_2O)$ = 27.800 g
$m(CuSO_4 * 5H_2O)$ = 24.969 g
$m(AgNO_3)$ = 16.987 g
$m(ZnSO_4 * 7H_2O)$ = 28.753 g
(m(NiSO4) = 15.475 g)

4. Weigh these amounts into the individual beakers and dissolve the substances in 100 mL of distilled water by stirring with a glass rod.

Preparation of the cell troughs

1. Insert two paper membranes between the half-cell blocks of each cell trough.

2. Insert two metal electrodes into the second outermost slot of the cell trough, depending on the combination of the half-cells.

3. Set the changeover switch (2) (see Fig. 2) to direct current, also the switch (8) on the ammeter and the rotating switch (15) on the voltmeter.

Performing the experiment

1. Before starting the measurements, pour the relevant salt solution into the half-cells of the metal electrodes to a depth of about 3 to 4 cm. You can start with the combination of copper and zinc.

2. Switch the demonstration unit to external measurement (6). The potential difference can now be read off on the unit. It

can be determined which electrode forms which pole by swapping the plus and minus poles. The poles are correctly connected if a positive value is displayed.

3. Then continue with the combinations copper/iron and silver/copper. These are sufficient to establish an electrochemical series.

4. If lead and nickel are also used, it is best to measure these against zinc or copper.

Evaluation

First look for the metal that forms the minus pole in all combinations. Then look for the metal which always forms the plus pole. The least noble and the noblest metals have therefore been identified and the other metals can be arranged on the basis of their potential differences in comparison to both these metals.

Results

Zinc always forms the minus pole in all combinations and is therefore the least noble metal in this experiment. Silver, on the other hand, always forms the plus pole and is the noblest metal in this experiment. An electrochemical series of the metals used here in this experiment can be established with the help of the remaining combinations and results.

Electrode 1	Electrode 2	Voltage ΔE	Plus pole	Minus pole
Cu	Ag	0.418 V	Ag	Cu
Cu	Fe	0.639 V	Cu	Fe
Cu	Zn	1.056 V	Cu	Zn
Zn	Ni	0.502 V	Ni	Zn
Zn	Pb	0.584 V	Pb	Zn

Zn < (Ni) < Fe < (Pb) < Cu < Ag

Non-noble Noble

Cleaning and disposal

All solutions must be disposed of in a waste container labelled for inorganic waste. The solutions must not be emptied into drains under any circumstances