Galvanic cells from a series of concentration, their potentials and how to calculate them (Item No.: P7401300)

Curricular Relevance

Area of Expertise: Chemie

Education Level: Klasse 10-13

Topic: Physikalische Chemie

Subtopic: Elektrochemie - Potenziale, Leitfähigkeit, Elektrolyse

Experiment: Galvanische Zellen als Konzentrationskette, ihre Potenziale und ihre Berechnung

Difficulty

Intermediate

Preparation Time

10 Minutes

Execution Time

10 Minutes

Recommended Group Size

2 Students

Additional Requirements:

- Filter paper strips

Experiment Variations:

Keywords:

galvanic cells, calculation of potential

Information for teachers

Introduction

Principle

Electrical voltages are not only measurable between different metals in solutions of their salts, but also between half-cells which are the same except for containing different concentrations of the salt solution. Such couples of the same half-cells with different salt concentrations are called “concentration series”. The voltages measurable from such concentration series are subject to a conformity to natural law which is expressed mathematically by the so-called “Nernst equation”.

Processes at the electrodes:

Oxidation process (anode) $Ag^{-} \rightarrow Ag^{+} + e^{-}$ (solution of lower concentration)

Reduction process (cathode) $Ag^{+} + e^{-} \rightarrow Ag$ (solution of higher concentration)

Concentration of solution c (red)	Concentration of solution c (ox)	$\frac{c_1}{c_2}$	$\frac{log c_1}{c_2}$	Voltage measured V- (20 °C)
0.1	0.01	10	1	1 * 0.058
0.01	0.001	10	1	1 * 0.058
0.001	0.0001	10	1	1 * 0.058
0.1	0.001	100	2	2 * 0.058 = 0.116
0.01	0.0001	100	2	2 * 0.058 = 0.116
0.1	0.0001	1000	3	3 * 0.058 = 0.174

The Table 1 shows that the voltages, or the potential differences, of this series of concentrations change proportionally to the logarithm of the quotient from c_1 and c_2 , and not proportionally to the concentration. The potential difference ΔE of concentration series can so be calculated from the equation:

$$\Delta E = 0.058V \cdot \frac{log c_1(red)}{c_2(ox)}$$

This relationship is only true for monovalent ions, such as silver ions. With multivalent ions the voltage decreases with the valency. We then have:

$$\Delta E = \frac{0.058V}{c_2(ox)}$$

This “Nernst equation” can be used to calculate the potentials of series of concentrations.

Educational objectives

The students will learn how to measure the potential between two half cells which are the same. Furthermore, the students will learn how to use the "Nernst equation". The term "Concentration series" is also introduced.

Preparation of the solutions:

Silver nitrate solution (0.1 mol/l): Add 8.49 g of silver nitrate to 250 ml distilled water. Stir well and fill up to 500 ml with distilled water.

Silver nitrate solution (0.01 mol/l): Add 50 ml of the Silver nitrate solution (0.1 mol/l) to 450 ml of distilled water.

Silver nitrate solution (0.001 mol/l): Add 50 ml of the Silver nitrate solution (0.01 mol/l) to 450 ml of distilled water.

Silver nitrate solution (0.0001 mol/l): Add 50 ml of the Silver nitrate solution (0.001 mol/l) to 450 ml of distilled water.

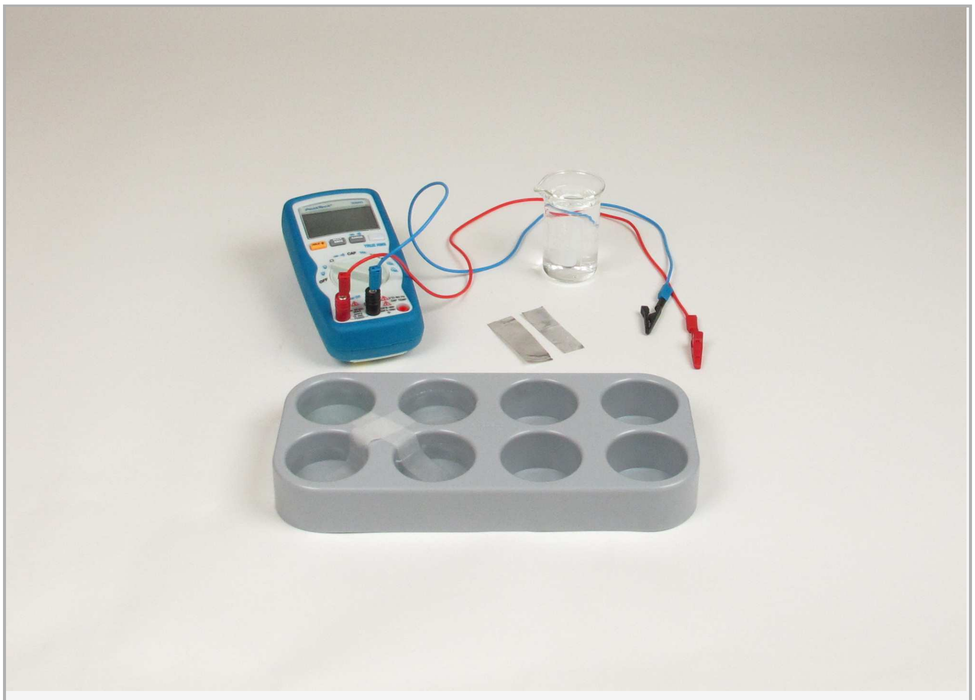

Fig. 1: Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	Digital multimeter 2005	07129-00	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	1
5	Alligator clip, insulated, 2 mm socket, 2 pcs.	07275-00	1
6	Block with 8 holes, d = 40 mm	37682-00	1
7	Coverage f.cell-meas.bloc,8 piec.	37683-00	1
8	Silver foil, 150 x150 x 0.1 mm, 25 g	31839-04	1
9	Glass beaker DURAN®, tall, 50 ml	36001-00	5
Additionally needed:			
	Filter paper strips		
	Silver nitrate solutions of concentrations (0.1,0.01,0.001,0.0001 mol/l)		

Safety information

Avoid contact of the chemicals with eyes and skin. Wear protective glasses!

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Introduction

Application and task

Application

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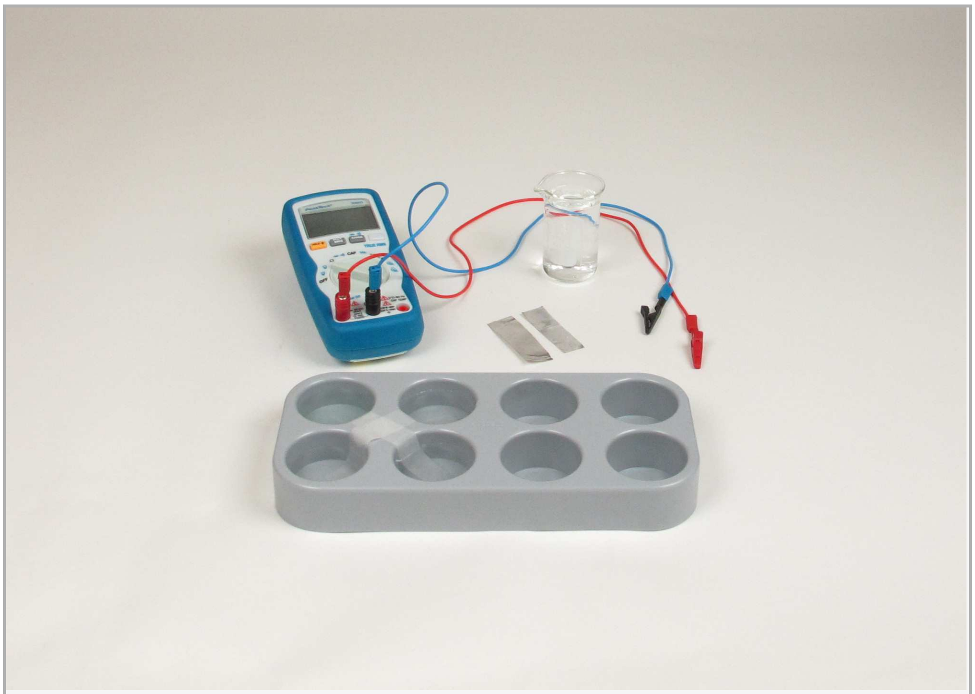
Task

Silver/silver nitrate half-cells are to be prepared, in which the concentrations of silver ions differ in steps of powers of ten. The voltages between the various combinations of these half-cells are to be measured. The evaluation of them is to lead to the Nernst equation.



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Additionally needed:			
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	Silver nitrate solutions of concentrations (0.1,0.01,0.001,0.0001 mol/l)		

Set-up and procedure

Fill silver nitrate solutions of different concentrations into measuring cells 1 to 4, as shown in Fig. 1. Start with cell 1 and concentration 0.0001 mol/l, then continue with cell 2 (0.001 mol/l), cell 3 (0.01 mol/l) and cell 4 (0.1 mol/l). The use of a 1 molar solution has been abstained from for reason of cost. Connect the 4 measuring cells as shown in Fig. 1, using keys made from filter paper strips but not wetted with potassium nitrate solution. Instead of using potassium nitrate solution, allow the silver nitrate solutions in the connected measuring cells to ascend up from the immersed strip ends until they meet at the middle of the strips (this method is always to be recommended, when the solutions which are connected contain the same ions).

Check that the crossed paper strips lie firmly against each other, so that a good flow is ensured in all directions.

There is no need to place covers on the measuring cells. Have a beaker containing pure water available, however, so that the silver electrodes can be rinsed in this after each measurement.

As shown in Fig. 1, connect the blue connecting cord to the earthed socket (negative input) and the red connecting cord to the voltage socket (positive input) of the measuring instrument. Fit crocodile clips on the other ends of these connecting cords, and use these to grasp the silver electrodes (= the pieces of silver foil of size 15 x 40 mm).

Now measure the voltages between the solutions from the lowest to the highest in the concentration series, i.e. firs dip the electrode which is connected to the earthed socket of the measuring instrument in the solution of lowest concentration, and the other electrode in the solution of next higher concentration (this is always the positive pole of such a concentration series). In other words, measure and note the voltages between the half-cells 1 + 2, 2 + 3 and 3 + 4. Between each measurement, be sure to rinse the electrodes briefly in the beaker containing pure (dis- tilled) water, and then to shake them to remove any drops of water.

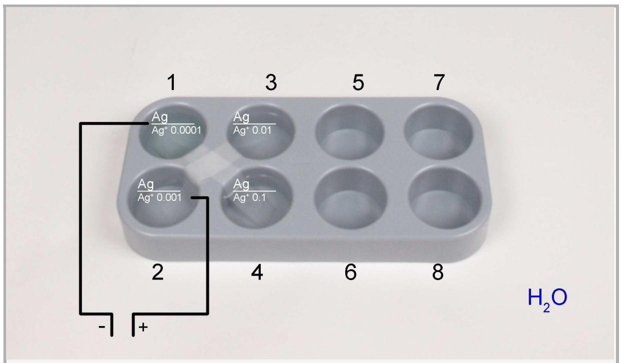

Fig. 2

Report: Galvanic cells from a series of concentration, their potentials and how to calculate them

Results - Question 1

Note down your observations and measurement values concerning the experiment.

Evaluation - Question 1

What are the processes at the electrodes?

Evaluation - Question 2

Create a table with: concentraton of solutions c_1, c_2, $\frac{c_1}{c_2}$, $\frac{log c_1}{c_2}$ and the voltage measured (20 °C).

Which conclusion can you make?

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Evaluation - Question 3

The potential difference ΔE of concentration series can so be calculated from the "Nernst equation". Give the "Nernst equation" and conclude how you have to adapt the original equation for multivalent ions.

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