Change in the voltage of a concentration series

(Item No.: P7401600)

Curricular Relevance

Area of Expertise: Chemie

Education Level: Klasse 10-13

Topic: Physikalische Chemie

Subtopic: Elektrochemie - Potenziale, Leitfähigkeit, Elektrolyse

Experiment: Veränderung der Spannung einer Konzentrationskette

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Filter paper strips

Experiment Variations:

Keywords:

concentration series, difference of potential

Information for teachers

Introduction

Principle

In a concentration series, the voltage is higher the greater the difference in the concentrations of the solutions in the half-cells. No voltage is measurable with a concentration series consisting of two half-cells which are exactly the same, e.g. copper electrodes in 0.1 molar copper sulphate solution. However, when ions (e.g. iodide ions) are added to one of the half-cells which form a sparingly soluble compound with the effective metal ions in the solution (e.g. Cu2+), then a part of the effective metal ions are lost by precipitation (iodide ions react with Cu2+ to form sparingly soluble copper(I) iodide).

The result is the formation of a difference in concentration between the two solutions in the half-cells, whereby the voltage of the concentration series increases. Similarly, when a complex former is added to one of the solutions (e.g. NH3 to Cu2+), the formation of the complex decreases the effective ionic concentration, and so also causes an increase in the voltage.

The addition of amoniac solution to copper sulphate solution causes the formation of the deep-blue ammoniated cupric sulphate complex, in which the effective copper ion is bound, as shown by the equation:

$$Cu^{2+} + 4\,NH_3 \rightarrow (Cu(NH_3))4)^{2+}$$

Bound copper ions are no longer able to contribute to potential formation, so that the effect is the same as a decrease in their concentration.

The voltage increases with the on-going decrease in the copper ion concentration. At somewhat more than 400 mV so that, despite further addition of ammonia solution, the copper ion concentration cannot be further decreased. The change in voltage in concentration series per power of ten is known to have a value of $\frac{0{,}058}{n}$ V (20 °C).

As n has the value 2 for copper ions, the voltage increases in this experiment by 0.029 V per power of ten decrease in the ionic concentration. With a maximum voltage of 0.420 V, we can therefore calculate that:

$$0,420 : 0,029 = 14,48$$

i.e. in our experiment, the copper ion concentration was decreased by around 14 powers of ten.

Educational objectives

The students will learn to comprehend the consequences that result from a change in the voltage of a concentration series due to e.g. precipitation.

Preparation of the solutions

Copper sulphate solution (0.1 mol/l): Add 7.95 g of copper sulphate to 250 ml distilled water, stir well. Fill up to 500 ml with distilles water.

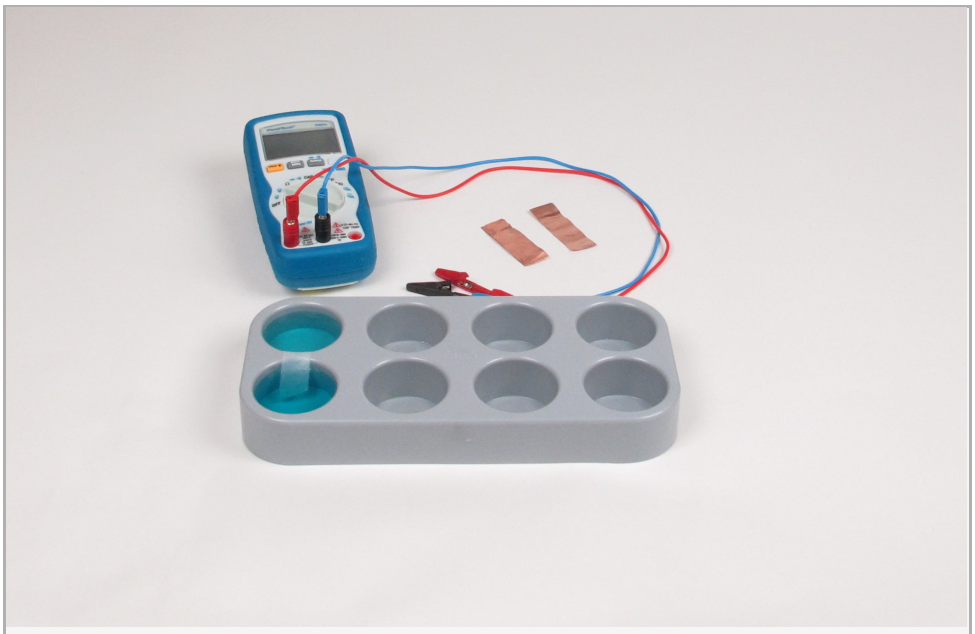

Fig. 1: Experimental set-up

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	Copper foil, 0.1 mm, 100 g	30117-10	1
7	Block with 8 holes, d = 40 mm	37682-00	1
8	Coverage f.cell-meas.bloc,8 piec.	37683-00	1
9	Glass beaker DURAN®, tall, 50 ml	36001-00	2
10	Pipette with rubber bulb	64701-00	1
Additionally needed:			
	Copper sulphate solution, c = 0.1 mol/l		
	Ammonia solution, concentrated		
	Filter paper strips		

Safety information

Concentrated ammonia solution causes burns and vapours with a biting smell rise up from the solution. Avoid contact of the chemical with eyes and skin. Do not breathe vapours! Wear protective gloves and protective glasses!

Introduction

Application and task

Application

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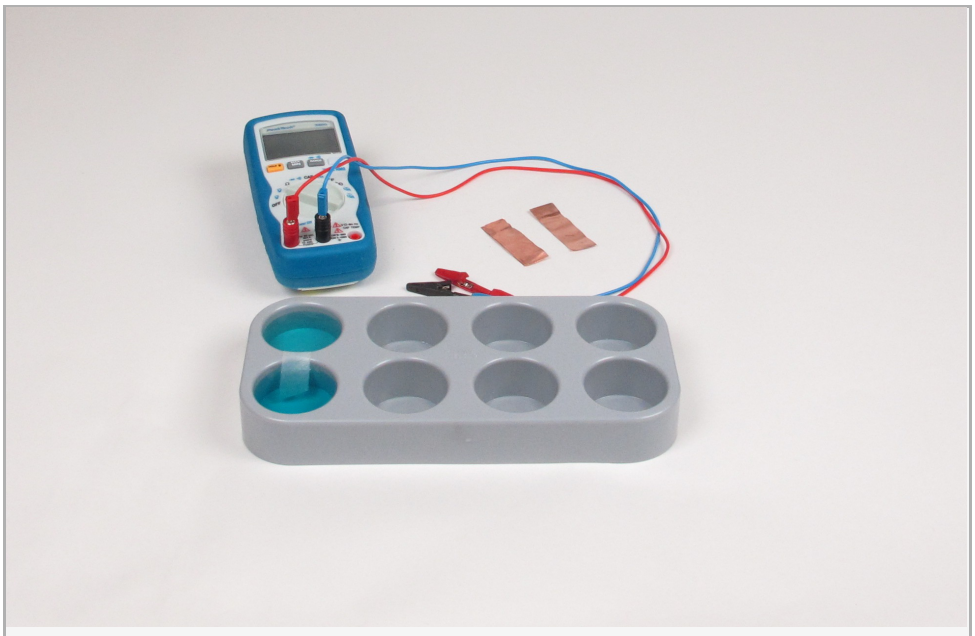
Task

Prepare a cell from two identical copper half-cells. After having connected a voltmeter, add concentrated ammonia solution drop wise to one of the half-cells until the voltage which is measured reaches a definite highest value.



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Set-up and procedure

As shown in Fig. 2, fill measuring cells 1 and 2 with 0.1 molar copper sulphate solution. Conductively connect the two measuring cells with a key made from a filter paper strip which is also wetted with 0.1 molar copper sulphate solution (allow the solutions to simply ascend up from the strip ends until they meet at the middle of the strip). Put a cover on measuring cell 1, but leave measuring cell 2 open.

Connect the copper electrodes with the measuring instrument, as shown in Fig. 1 (set the measuring range to 2 V-), and insert the electrode which is connected to the voltage socket (= positive pole connection) in measuring cell 1 and the other electrode in measuring cell 2.

Measure the voltage!

Now slowly drop concentrated ammonia solution (25%) into the copper sulphate solution in measuring cell 2, and stir it a little with the electrode. Keep dropping ammonia solution in, until the voltage no longer changes.

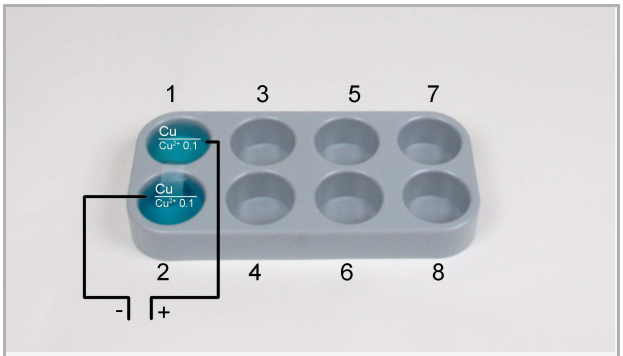

Fig. 2

Report: Change in the voltage of a concentration series

Results - Question 1

What was the measured voltage before addition of ammonia solution?

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Results - Question 2

What did you observe after the addition of ammonia solution?

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Evaluation - Question 1

What happens after the addition of ammonia solution to the copper sulphate solution?

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Evaluation - Question 2

Give the equation for formation of the ammoniated curpric sulphate complex.

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Evaluation - Question 3

Explain the increase in voltage after addition of ammonia solution.

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