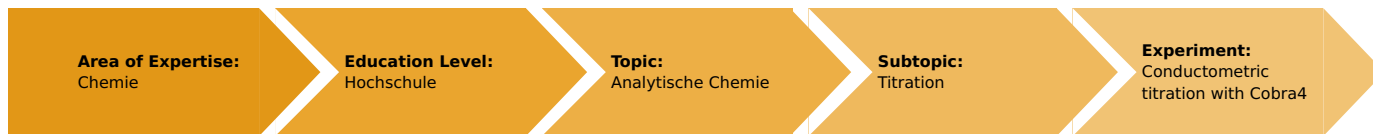


Conductometric titration with Cobra4 (Item No.: P3060760)

Curricular Relevance



Difficulty



Intermediate

Preparation Time



10 Minutes

Execution Time



10 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- Precision balance, 620 g / 0.001 g
- PC with USB interface, Windows XP or higher

Experiment Variations:

Keywords:

electrolyte, electrical conductance, specific conductance, ion mobility, ion conductivity, conductometry, volumetry

Overview

Short description

Principle

The electric conductivity of aqueous electrolyte solutions is determined by the type and number of charge carriers at constant temperature. Characteristic changes in conductivity are connected with changes in the ionic composition of reacting systems. These can be used in the conductometric titration as end point indicators.



Fig. 1: Experimental setup.

Safety instructions



When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing. Please refer to the appendix for detailed safety instructions.

Safety instructions



When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing. Please refer to the appendix for detailed safety instructions.

Caustic soda solution, 0.1 N

H290: May be corrosive to metals.

P234: Keep only in original container

P280: Wear protective gloves/protective clothing/eye protection/face protection.

Hydrochloric acid, 0.1 N

H290: May be corrosive to metals.

P234: Keep only in original container.

Sulphuric acid, 0.1 N

P280: Wear protective gloves/protective clothing/eye protection/face protection.

H290: May be corrosive to metals.

Barium hydroxide

H332: Harmful if inhaled.

H302: Harmful if swallowed.

H314: Causes severe skin burns and eye damage.

H332: Harmful if inhaled.

P280: Wear protective gloves/protective clothing/ eye protection/face protection.

P301+330+331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.

P305+351+338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do – continue rinsing.

P309+310: IF exposed or you feel unwell: Immediately call a POISON CENTER or doctor/physician.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	2
2	Cobra4 Sensor-Unit Drop Counter	12636-00	1
3	Cobra4 Sensor-Unit Conductivity+	12632-00	1
4	USB charger for Cobra4 Mobile-Link 2 and Wireless/USB-Link	07932-99	2
5	curricuLAB measureLAB	14580-61	1
6	Holder for Cobra4 with support rod	12680-00	2
7	Conductivity temperature probe Pt1000	13701-01	1
8	Magnetic stirrer without heating, 3 ltr., 230 V	35761-99	1
9	Magnetic stirring bar 30 mm, cylindrical	46299-02	1
10	Retort stand, h = 750 mm	37694-00	1
11	Right angle boss-head clamp	37697-00	3
12	Burette clamp, roller mount., 2 pl.	37720-00	1
13	Burette, lateral stopcock, Schellbach, 25 ml	36506-01	1
14	Beaker, low, BORO 3.3, 250 ml	46054-00	1
15	Weighing dishes, square shape, 84 x 84 x 24 mm, 25 pcs.	45019-25	1
16	Volumetric flask 50 ml, IGJ12/21	36547-00	1
17	Volumetric flask 100 ml, IGJ12/21	36548-00	1
18	Volumetric flask 250 ml, IGJ14/23	36550-00	1
19	Volumetric pipette, 5 ml	36577-00	3
20	Volumetric pipette, 10 ml	36578-00	2
21	Pipettor	36592-00	1
22	Pipette dish	36589-00	1
23	Funnel, glass, top dia. 55 mm	34457-00	1
24	Funnel, glass, top dia. 80 mm	34459-00	1
25	Spoon, special steel	33398-00	1
26	Wash bottle, plastic, 500 ml	33931-00	1
27	Pasteur pipettes, 250 pcs	36590-00	1
28	Rubber caps, 10 pcs	39275-03	1
29	Sulphuric acid, 0.5M 1000 ml	48462-70	1
30	Hydrochloric acid, 0.1M 1000 ml	48452-70	1
31	Acetic acid, 0.1 M sol., 1000 ml	48126-70	1
32	Caustic soda sol., 0.1M 1000 ml	48328-70	1
33	Barium hydroxide 250 g	30034-25	1
34	Water, distilled 5 l	31246-81	1
35	Standard solution 1413µS/cm(25°C), 460ml	47070-02	1

Tasks

Perform the following conductrometric titrations and record your measurement data with measureLAB  and the Cobra4 sensors 'Chemistry' & 'Drop counter'



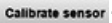
- approximately 0.1 molar barium hydroxide solution with 0.1 molar sulphuric acid,
- approximately 0.1 molar hydrochloric acid with 0.1 molar sodium hydroxide solution and
- approximately 0.1 molar acetic acid with 0.1 molar sodium hydroxide solution.

Other samples can alternatively be set in advance for conductrometric determination of their concentration contents.

Setup and procedure

Setup



- Prepare the solutions required for the experiment as follows:
 - 0.1 molar $\text{Ba}(\text{OH})_2$ solution: Weigh 7.9 g of barium hydroxide ($\text{Ba}(\text{OH})_2 \cdot \text{H}_2\text{O}$) into a 250 ml volumetric flask, add some distilled water to dissolve it, then make up to the mark with distilled water. Should the solution be turbid (a pointer that BaCO_3 is present in the solution), filter it prior to use.
 - 0.1 molar H_2SO_4 solution: Pipette 10 ml of 0.5 M sulphuric acid into a 50 ml volumetric flask and make up to the mark with distilled water.
 - 0.1 molar CH_3COOH solution: Pipette 10 ml of 1.0 M acetic acid into a 100 ml volumetric flask and make up to the mark with distilled water.
- Set up the experiment as shown in Fig. 1.
- Attach the burette to the retort stand using the burette holder.
- Combine the Cobra4 Sensor Unit Conductivity+ and the Cobra4 Drop Counter with the Cobra4 Wireless-Links.
- Attach them to the retort stand with the holders for Cobra4 and right angle clamps.
- Connect the conductivity/temperature probe to the electrode input of the Cobra4 Sensor Unit Conductivity+.
- Start the PC and connect it the Cobra4 Wireless Link with a USB socket or wireless connection.
- After the Cobra4 Wireless-Links have been switched on, the sensors are automatically recognized. The respective ID numbers are allocated to the sensors, which are indicated in the displays of the Cobra4 Wireless-Links.
- Call up the software "measureLAB" .
- Boot the experiment "Conductometric titration with Cobra4" (experiment > open experiment). The measurement parameters for this experiment are loaded now.
- Adjust the magnetic stirrer to a medium stirring speed.
- **For calibration:** Pour some standard solution into a beaker and immerse the well-rinsed probe into the solution (*Advice:* Both platinum electrodes of the probe have to be covered completely with the solution).
- Go to  and then click on Sensors/channels and select "Conductivity σ ". To perform 1-point calibration, click on .
- Enter the corrected value for the conductivity at a given temperature (cf. Fig. 2). You can find this value on the label of the standard solution (at 25 °C with $C = 1413 \mu\text{S}/\text{cm}$) Click the "Apply corrected value" button and repeat this step for the second point of calibration. Finish the calibration with "OK".

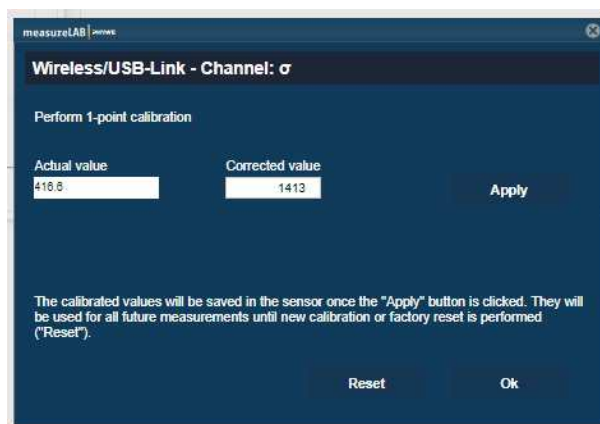



Fig. 2: Settings for the calibration mode of the sensor.

Procedure

- Place a 250 ml glass beaker containing approximately 100 ml of distilled water and a magnetic stirrer bar on the magnetic stirrer.
- Immerse the previously well-rinsed conductivity cell in the water and fix it in one of the electrode holes of the Cobra4 Drop Counter.
- Pipette 5 ml of the 0.1 M barium hydroxide solution into the water in the beaker. Fill the burette with 0.1 M sulphuric acid and fix it above the beaker.
- Place the outlet of the burette in such a manner that the Cobra4 Drop Counter is able to record every single drop. For this the outlet of the burette should be in the center of the light barrier.
- Start the measurement with .
- Add the standard solution dropwise until a total of 10 ml has been added.
- Terminate the measurement with .
- Save your project by clicking on the button  in the top bar.
- Fig. 3 shows the graph as it is presented by the program.
- Carry out measurements with other acids using the same procedure.
- In each case pipette 5 ml of the 0.1 M acid into the glass beaker containing 100 ml of distilled water, and fill the burette with 0.1 M sodium hydroxide solution.

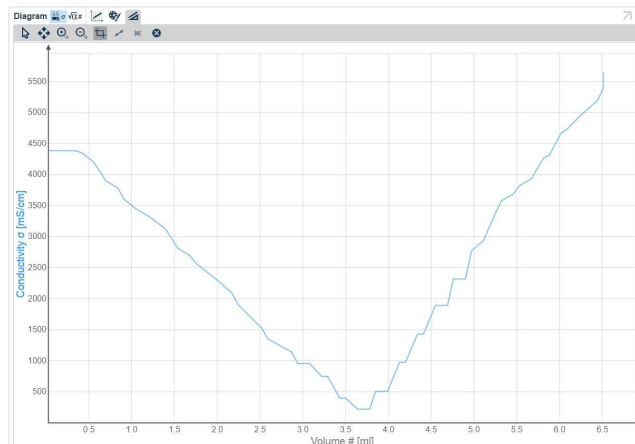


Fig. 3: Change in the specific conductivity κ in the titration of an approximately 0.1 molar barium hydroxide solution ($V = 5$ ml) with sulphuric acid ($c = 0.1$ mol / l).

Theory and evaluation

The electrical conductance G of an electrolytic solution and the specific conductivity κ calculated from it are comprised (additively) of the different contributions of the individual ion types:

$$\kappa = K \cdot G = \sum |z_i| u_i c_i F \quad (1)$$

where

K Cell constant (quotient of the distance l and area A of the electrodes in the measured cell)

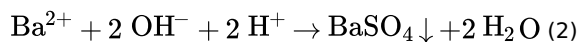
z_i Charge number

u_i Ion mobility

c_i Concentration of ion i

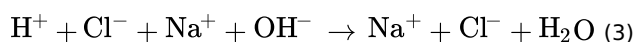
F Faraday constant

According to equation (1) an increase or decrease in conductivity at constant temperature is to be expected when the composition (c_i , u_i) of the system to be examined is changed. In the titration of a given sample of barium hydroxide solution with sulphuric acid both ion types of the added standard solution react with the components of the solution being determined by forming undissolved, i.e. non-dissociated products.



According to equation (1), a constant decrease in the quantity being measured κ to the point of neutrality (Fig. 3) results from the total depletion of charge carriers. Subsequent to this, the ions added in excess from the sulphuric acid are no longer converted, thus the conductivity increases approximately linearly.

In contrast, the observable decrease in the specific conductivity in the neutralisation of a strong acid (HCl) with a strong base (NaOH) is due to the exchange of hydronium ions having high mobility ($u_+ = 315 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$) compared to the sodium ions with a low mobility ($u_+ = 43 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$) according to equation (1):



In the case of overtitration, the conductivity of the concentration of the hydronium ions with high ion mobility added in excess ($u = 174 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$) increases linearly (Fig. 4).

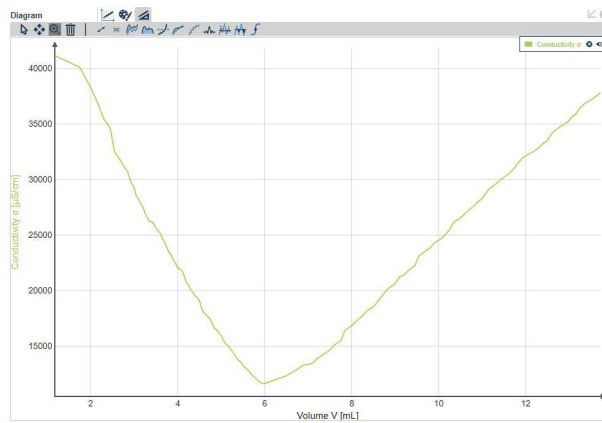


Fig. 4 :Titration diagram for the neutralisation of an approximately 0.1 molar HCl (V = 5 ml) with NaOH (c = 0.1 mol / l).

The depicted titration curve in Fig. 5 is valid for the reaction of a weak acid (CH_3COOH) with a strong base (NaOH).

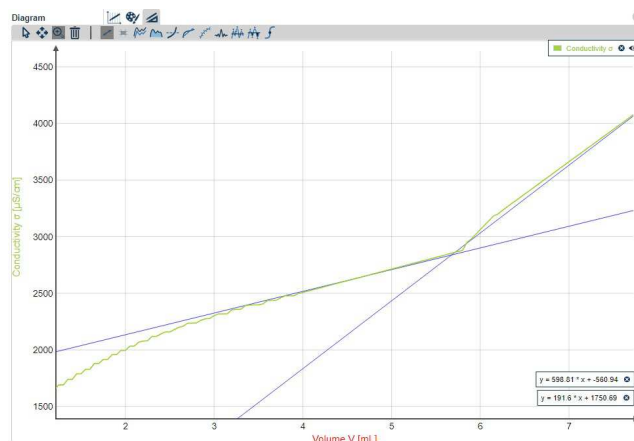
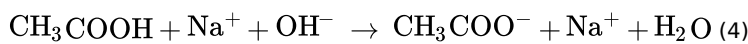


Fig. 5: Conductivity as a function of the volume of added standard solution in the titration of an approximately 0.1 molar acetic acid solution (V = 5 ml) with a sodium hydroxide solution (c = 0.1 mol / l).

Due to the low autodissociation, the acid shows a comparatively low conductivity. As a result of the dissociation being suppressed further due to salt formation, the conductivity first continues to decrease. Before reaching the point of neutrality, the conductivity slightly increases due to the increased contribution of the sodium and acetate ions to the concentration. After the acid has been completely transformed to the salt, the measured conductivity increases approximately linearly resulting from the continued addition of the standard solution as discussed in the above cases due to the addition of excess titrators. The point of neutrality can be taken from the titration curves by determining the local conductivity minimum, in the case of the acetic acid by determining the point of intersection of the two straight lines (see Fig. 5). Use to generate regression lines with your data and consequently, determine the cross section of the two regression lines using the tool.

The concentration c_2 and thus the quantity m_2 of ions in the given sample having a volume V_2 can be calculated from the consumption V_1 of the known concentration c_1 of the standard solution using the relationship

$$c_1 V_1 = c_2 V_2 = \frac{m_2}{M_2} \quad (5)$$

where

M_2 Molar mass of the electrolyte to be determined

Data and results

The titration curves are shown in Figs. 3 to 5. The volumes of the standard solution required to reach the equivalence points can be determined from them, i.e. $V_1 = 4.75 \text{ ml H}_2\text{SO}_4$ (Fig.3), $V_1 = 4.95 \text{ ml NaOH}$ (Fig. 4) and $V_1 = 6.25 \text{ ml NaOH}$ (Fig. 5). From equation (5), the concentrations $c_2 = 0.095 \text{ mol/l Ba(OH)}_2$, $c_2 = 0.099 \text{ mol/l HCl}$ and $c_2 = 0.125 \text{ mol/l CH}_3\text{COOH}$ can be calculated, and from these the masses in the 5 ml test volumes; $m_2 = 81.38 \text{ mg Ba(OH)}_2$, $m_2 = 18 \text{ mg HCl}$ and $m_2 = 37.5 \text{ mg CH}_3\text{COOH}$.

Appendix

Disposal

The diluted and neutralised solutions of the used acids and bases can be disposed by rinsing into the drain.

Appendix

Hazard symbol, signal word

Caustic soda solution, 0.1 N



Hazard statements

Precautionary statements

H290: May be corrosive P234: Keep only in original container to metals.

Attention

Hydrochloric acid, 0.1 N



H290: May be corrosive P234: Keep only in original container. to metals.

Attention

Sulphuric acid, 0.1 N



H290: May be corrosive - to metals.

Attention

Barium hydroxide



H332: Harmful if inhaled.

P280: Wear protective gloves/protective clothing/ eye protection/face protection.

H302: Harmful if swallowed.

P301+330+331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.

H314: Causes severe skin burns and eye damage.

P305+351+338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do - continue rinsing.

Danger

P309: IF exposed or you feel unwell:

P310: Immediately call a POISON CENTER or doctor/physician.