

Conductometric titration of a hydrochloric acid solution

Aims of the experiment

- Getting to know the titration process of a conductometric acid-base titration.
- Understanding the interaction of hydronium and hydroxide ions and their reaction with water.
- Learning to determine the equivalence point from the conductivity measurement.
- Understanding the high conductivity of the hydronium and hydroxide ions using the Grotthuss mechanism.

Principles

By means of the conductivity measurement, both acid-base titrations and precipitation titrations can be tracked.

Tracking an acid-base titration is conductometrically possible, since both hydronium and hydroxide ions have a very high conductivity. The high conductivity of hydronium and hydroxide ions compared to other ions such as Na^+ and Cl^- ions in aqueous solutions can be explained by the Grotthuss mechanism. This is based on the assumption that hydronium and hydroxide ions do not move through aqueous solution as particles in the electric field. In fact, the effective movement of the protons takes place through the reorientation of hydrogen bonds along water molecule chains (see Fig. 1). These ions therefore move faster in aqueous solutions than other ions.

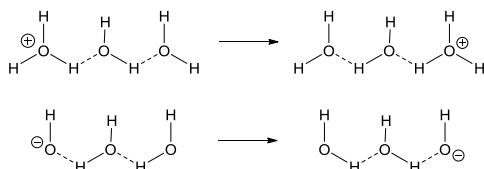


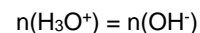
Fig. 1: Conductivity mechanism of the hydronium ions (top) and the hydroxide ions (bottom) in aqueous solutions.

At the beginning of the experiment, there are a large number of hydronium ions in the aqueous hydrochloric acid solution and the conductivity of this solution is thus particularly high. If ions with an opposite charge such as hydroxide ions are now added to a sodium hydroxide solution, water is formed, since the hydronium ions are neutralised by the hydroxide ions.



The conductivity of the electrolyte solution decreases. The number of hydronium and hydroxide ions is balanced exactly at the equivalence point of the reaction and the conductivity of the solution passes through a minimum level.

This is expressed by the following chemical equation:



Adding more sodium hydroxide solution increases the conductivity of the solution again, since there is now an excess of hydroxide ions.


The exact equivalence point of the reaction can be determined by two regression lines. The regression line of the falling curve area crosses the regression line in the rising curve area at exactly the minimum level of the graph, the equivalence point of the titration.



Fig. 2: Experiment apparatus for a conductometric titration.

Risk assessment

Sodium hydroxide solution in the used concentration is not classified as dangerous goods. Hydrochloric acid can cause skin irritation. For this reason, protective goggles and safety gloves should still be worn during the experiment.

Hydrochloric acid, 0.1 mol/l	
 <p>Signal word: Caution</p>	Hazard statements H290: May be corrosive to metals.
	Precautionary statements P234: Keep only in original container. P390 – Absorb spillage to prevent material damage.

Equipment and chemicals

1	Pocket-CASSY 2 Bluetooth	524 018
1	CASSY Lab 2	524 220
1	Conductivity adapter S	524 0671
1	Conductivity sensor	529 670
1	Magnetic stirrer mini	607 105
1	Stirring magnet, 40 mm x 20 mm diam.	604 592
1	Beaker, DURAN, 250 ml, squat	664 103
1	Measuring cylinder, 100 ml, with plastic base	665 754
1	Bulb pipette Boro 3.3, 10 ml, one mark	665 975
1	Pipetting ball (Peleus ball)	666 003
1	Burette, clear glass, 25 ml	665 845
1	Funnel, PP, 25 mm diam.	665 816
1	Burette clamp for 1 burette, roller clamp	666 559
1	Stand base, V-shaped, small	300 02
1	Stand rod, 47 cm, 12 mm diam.	300 42
1	Double, crossed bosshead, 0...16 mm	666 543
1	Universal clamp, 0...80 mm	666 555
1	Hydrochloric acid, 0.1 mol/l, 500 ml	674 6950
1	Sodium hydroxide solution, 0.1 mol/l, 500 ml	673 8410

Additionally recommended:
 Rechargeable battery for Pocket-CASSY 2 Bluetooth*
 524 019
 Bluetooth dongle* 524 0031

Set-up and preparation of the experiment

Set-up of equipment

For the conductometric measurement, an apparatus for titration is assembled, consisting of a magnetic stirrer, beaker (250 ml), burette, burette clamp and stand (see Fig. 2). For this, the burette clamp is fixed to the stand rod with stand base and the burette clamped into the clamp. The conductivity sensor is finally fixed to the stand rod using a universal clamp and a double, crossed bosshead and connected to the Pocket-CASSY. For this, connect the conductivity electrode to the Pocket-CASSY 2 Bluetooth using the conductivity adapter S. If the Pocket-CASSY 2 is to be operated via Bluetooth, it must be connected to the computer using a Bluetooth dongle.


Note: When assembling, it should be ensured that the electrode is immersed into the liquid so that it is sufficiently covered, but does not come into contact with the rotating stirring magnet.

Preparations for the titration

Preparing the solutions: Using the measuring cylinder, 100 ml of water is poured into a 250 ml beaker and 10 ml 0.1 M of hydrochloric acid added to it with a pipette. Finally, add a stirring magnet to the beaker. The burette is filled with 20 ml 0.1 M of sodium hydroxide solution using the funnel.


Performing the experiment

1. Load CASSY Lab 2 settings.

2. First switch on the magnetic stirrer and adjust the rotation speed of the stirring magnet. Then record an initial value with . Alternatively, press the button on the pocket CASSY.

Note: The magnetic stirrer should be set to stir quickly enough so that the solutions mix thoroughly and so that it quickly levels out to a constant measured value.

3. Now add sodium hydroxide solution in 0.5 ml increments and, after setting a constant conductivity value, manually

record the measured value for each increment with  or by pressing the button on the pocket CASSY.

Observation

During titration, the conductivity is tracked depending on the added volume of sodium hydroxide solution (see Fig. 3).

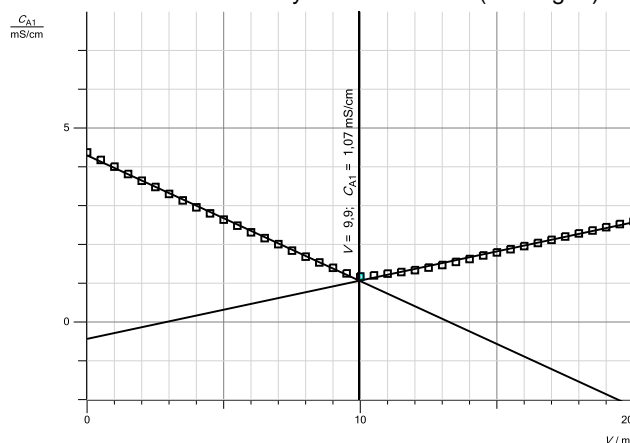


Fig. 3: Illustration of the conductivity depending on the added volume of a sodium hydroxide solution.

During the conductometric titration, the conductivity of the solution first decreases steadily with the addition of the sodium hydroxide solution. After adding approx. 10 ml NaOH solution, the minimum level of conductivity is reached and then rises steadily as more NaOH solution is added.

Evaluation

To determine the equivalence point from the conductometric measurement, two lines of best fit are first set using the measured values. For this, click on the diagram with the right mouse button and select **Perform adjustment** → **Line of best fit**. To create the first regression line, the left branch of the conductivity curve is marked. Repeat the adjustment for the second regression line for the right branch of the measurement. The equivalence point, which can be highlighted via **Place marker** → **vertical line**, is located at the intersection of both lines. The equivalence point determined here is at a volume of 9.9 ml of NaOH solution and a conductivity of 1.07 mS/cm.

Result

It has been shown that an acid-base titration can be conductometrically tracked. It can also be observed that both hydronium ions and hydroxide ions have a high conductivity. For this reason, the equivalence point is marked as a minimum level in the conductivity. At this point, the number of hydronium ions and hydroxide ions is equal and the ions

neutralise. However, if there is an excess of hydronium or hydroxide ions, the conductivity is comparatively higher. It could be shown that when titrating strong acids and bases in an aqueous solution, the equivalence point can be conductometrically determined.

Cleaning and disposal

Dispose of the solution in the drain flushing with large amounts of water.