

Conductometric titration of a hydrochloric acid solution with pH measurement

Aims of the experiment

- Getting to know an acid-base titration with two different measuring methods.
- Identifying the equivalence point of strong acids with bases as a neutral point when performing a titration.
- Understanding the interaction of hydronium and hydroxide ions and their reaction with water.
- Understanding water as an ampholyte, which can react as both an acid and a base.

Principles

During the conductometric titration with pH measurement, a conductivity and a pH measurement are carried out in parallel so that the equivalence point can be determined simultaneously with two measuring methods.

With the help of the conductivity measurement, both acid-base titrations and precipitation titrations can be tracked. For acid-base titrations, conductometric tracking is possible, since both hydronium and hydroxide ions have a very high conductivity compared to other ions (Grotthuss mechanism, for description see C3.5.2.1).

Hydrochloric acid is titrated with sodium hydroxide solution. To begin with, there are a large number of hydronium ions in the hydrochloric acid solution which significantly increase the conductivity of this solution. If ions with an opposite charge such as hydroxide ions are now added through the addition of sodium hydroxide solution, water is produced, 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 and the conductivity of the solution passes through a minimum level.

The following applies: $n(\text{H}_3\text{O}^+) = n(\text{OH}^-)$

When adding more sodium hydroxide solution, the conductivity increases again, since there is now an excess of hydroxide ions. Using the measured values obtained in the conductivity measurement, two regression lines can be set, which cross at a minimum level, the equivalence point.

In parallel with this, the change in pH value is tracked. In diluted solutions, the pH value is determined by the negative decadic logarithm of the hydronium ion concentration $c(\text{H}_3\text{O}^+)$ as follows:

$$\text{pH} = -\log(c(\text{H}_3\text{O}^+)) \text{ bzw. } c(\text{H}_3\text{O}^+) = 10^{-\text{pH}}$$

In the pH measurement, the equivalence point represents the point of inflexion of the titration curve, since the change rate of the pH value is at its maximum at this point. If strong acids and bases are titrated against one another in an aqueous solution, then the equivalence point is at the neutral point and the pH value is 7.



Fig. 1: Experiment apparatus for a conductometric titration with pH measurement.

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	Sensor-CASSY 2.....	524 013
1	CASSY Lab 2.....	524 220
1	Conductivity adapter S.....	524 0671
1	Conductivity sensor.....	529 670
1	pH adapter S.....	524 0672
1	pH sensor with plastic shaft, BNC.....	667 4172
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.....	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, 450 mm, 12 mm diam.....	666 523
1	Saddle base.....	300 11
1	Stand rod, 25 cm, 12 mm Ø.....	300 41
2	Double, crossed boss head, 0...16 mm.....	666 543
2	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, 500ml.....	673 8410
1	Buffer solution pH 4.00, 250 ml.....	674 4640
1	Buffer solution pH 7.00, 250 ml.....	674 4671

Set-up and preparation of the experiment

Set-up of equipment

For the conductometric titration with pH measurement, an apparatus for titration is assembled, consisting of a magnetic stirrer, beaker (250 ml), burette, burette clamps and stands (see Fig. 1). For this, the burette clamp is fixed to the stand rod with stand base and the burette is clamped into the clamp. The pH electrode is also fixed to the stand rod using a double, crossed boss head and a universal clamp. The conductivity sensor is also fixed to the stand rod using a double, crossed boss head and a universal clamp, which sits in the stand saddle base. Both sensors are connected with sensor-CASSY 2. For this, connect the pH electrode via pH adapter S to input channel A and the conductivity sensor via conductivity adapter S to input channel B.

Note: When assembling, it should be ensured that the electrodes are immersed in the liquid in such a way that they are sufficiently covered, but do not come into contact with the stirring magnet.

Preparation of the solutions

100 ml of water is measured with the measuring cylinder and poured into the 250 ml beaker, adding 10 ml, 0.1 M of hydrochloric acid with a pipette. The burette is filled with 20 ml of 0.1 M sodium hydroxide solution using the funnel.

Preparations for the measurement with CASSY

1. [Load CASSY Lab 2 settings.](#)
2. For an exact measurement, the pH electrode must be calibrated before carrying out a new measurement:
3. In settings pHA1, select **Correct**.
4. Rinse pH electrode with distilled water, immerse in the buffer solution pH 7.00 and stir it a little.
5. Enter 7.00 as the first reference value and after reaching a stable measured value, press the **Correct offset** button.
6. Rinse the electrode with distilled water and immerse in the buffer solution pH 4.00 and stir it a little.
7. Enter 4.00 as the second reference value and, after a brief waiting period, confirm with **Correct factor**.
8. The pH electrode is now calibrated. It can now be immersed in the hydrochloric acid solution like the conductivity electrode and fixed in place.

Note: To achieve more accurate measurement results, the pH electrode can be recalibrated after long periods of storage.

Performing the experiment

1. First switch on the magnetic stirrer and adjust the rotation speed of the stirring magnet. Then record an initial value by clicking on the button . Alternatively, press F9.
2. Record the first measured value by pressing /F9.
3. Now add sodium hydroxide solution in 0.5 ml increments and, after setting a constant pH and conductivity value, manually record the measured value for each increment.

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.

Observation

During titration, both the conductivity and the pH value are recorded depending on the added volume of sodium hydroxide solution (see Fig. 2).

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. When additional basic solution is added, the conductivity of the solution steadily increases again, although the rise is now more gradual. When the pH value is observed during the titration, then it first increases only slightly by the initial pH value 1.9. The slope of the curve inclines ever more steeply until it passes through an inflection point at a pH value of 6.1, then flattens and achieves a pH value of 11.3 as an end value.

Evaluation

During titration with sodium hydroxide solution, both by the conductivity and the pH value of the hydrochloric acid solution are measured (see Fig. 2).

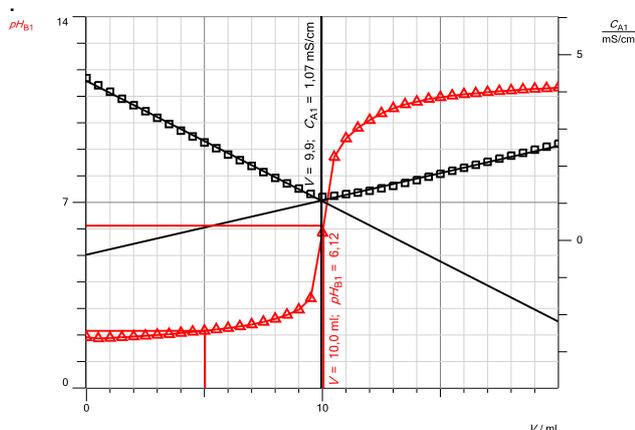


Fig. 2: Illustration of the conductivity (black) and the pH value (red) depending on the addition of a sodium hydroxide solution.

Determination of the equivalence point from the conductivity

To determine the equivalence point from the conductometric measurement, two lines of best fit are first set through the measured values. For this, click on the diagram with the right mouse button and select **Perform adjustment** → **Line of best fit**. For the creation of the first regression lines, 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 marked via **Place marker** → **vertical line** lies at the intersection point of both lines. The equivalence point determined here is at a volume of 9.9 ml NaOH solution and a conductivity of 1.07 mS/cm.

Determination of the equivalence point from the measurement of the pH value

In order to determine the equivalence point from the pH value measurement, click on the diagram with the right mouse button, select **Further assessments** → **Determine equivalence point** and mark the desired curve area. The determined equivalence point is shown in the status line and can be dragged and dropped into the diagram as text. The experimentally determined value is at a volume of 10 ml of sodium hydroxide and a pH value of 6.12.

Result

Both with the conductometric measurement and with the pH value measurement, the same equivalence point of an acid-base titration can be determined. This is due to the fact that the same chemical process can be verified in a different way. At the equivalence point, the number of hydronium ions and hydroxide ions is equal and the system is neutral. It can also be shown in the conductivity measurement that both hydronium ions and hydroxide ions have a high conductivity. In the conductivity measurement, the equivalence point is marked by a minimum level of the conductivity. In the pH measurement, the point of inflection of the titration curve is the equivalence point. At this point, the change rate of the pH value is at its maximum.

It could be verified in this experiment using two different measuring methods that the equivalence point at the neutral point is pH=7 during the titration of strong acids and bases in aqueous solution.

Cleaning and disposal

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