Practical work N°3. Measurement of uncertainty: Application to Acid–Base titration

Introduction

In scientific experiments, particularly in chemistry, uncertainty is an essential parameter that quantifies the reliability of the obtained result.

2. Types of measurement

2.1. Direct measurement: Obtained directly using measuring instruments (e.g., measuring pressure, conductivity, or pH using appropriate devices).

2.2. Indirect measurement: Derived through calculations based on other measured values (e.g., calculating energy, mass, or concentration from measured parameters).

3. Types of uncertainty

3.1. Absolute uncertainty (Δx): Represents the maximum possible error in a measurement. It is expressed as an absolute value, without considering the magnitude of the measurement. It can be determined by repeating the experiment several times to estimate the variation in the results, and calculating the average of the measured values.

$$x_0 = \frac{x_0 + x_1 + x_2 + \cdots x_{\mathrm{n}}}{n}$$

$$\Delta x = \frac{|x_0 - x_{max}| + |x_0 - x_{min}|}{2}$$

Where : $x = x_0 \mp \Delta x$

With: $x_0 - \Delta x \leq x \leq x_0 + \Delta x$

3.2. Relative uncertainty:

The relative uncertainty expresses the ratio between the absolute uncertainty and the measured value. It is given by the formula:

$$\frac{\Delta x}{x_0}$$

3.3. Measurement accuracy: It is often expressed as a percentage to indicate how close a measured value is to the true or accepted value. A smaller percentage uncertainty corresponds to a more accurate measurement.

Percentage uncertainty = $\frac{\Delta x}{x_0}.100$ (%)

4. Acid–Base titration

An acid–base titration is a quantitative analytical method used to determine the unknown molar concentration of an acid or a base by neutralizing it with a standard solution of known concentration.

The reaction between a strong acid and a strong base is represented by:

$$HA + BOH \rightarrow AB + H_2O$$

At the equivalence point, the number of moles of hydrogen ions (H^+) supplied by the acid equals the number of hydroxide ions (OH^-) supplied by the base.

$$n_{Acid} = n_{Base} \Leftrightarrow C_{acid} . V_{acid} = C_{base} . V_{base}$$

$$C_{acid} = \frac{(C_{base} . V_{base})}{V_{acid}}$$

5. Objective of the experiment

The objective of this practical work is to understand the concept of measurement uncertainty and to apply it to the determination of the molar concentration of a solution through an acid–base titration.

6. Materials and chemicals

Materials	**Chemicals**
- Burette with stand and clamp. - Graduated cylinder - Erlenmeyer flask - Funnel	- HCI solution of unknown concentration - NaOH solution with a concentration of 0.1 mol/L - Color reagent (bromothymol blue).

7. Experimental procedure

- Fill the burette with the sodium hydroxide solution of known concentration C = 0.1 mol/L and adjust the zero mark carefully.
- Using a graduated cylinder, take 10 ml of hydrochloric acid solution (HCl).
- Put it in a 250 ml erlenmeyer flask.
- Add few drops of bromothymol blue (which changes from yellow to blue at neutrality).
- Titrate by slowly adding the NaOH solution from the burette while stirring until the color changes (the endpoint).
- Record the final burette reading and calculate the volume of base used V_{NaOH}.