CLIL - Titration

Titration is a common laboratory method of quantitative analysis that can be used to determine the unknown concentration of a known reactant (analyte). The basis of the method is a chemical reaction of a standard solution (titrant) with a solution of an analyte. The analyte is a solution of the substance whose concentration is unknown and sought in the analysis. The titrant (described T) is a solution in which the concentration of a solute is precisely known. Because volume measurements play a key role in titration, it is also known as volumetric analysis. Usually it is the volume of the titrant required to react with a given quantity of an analyte that is precisely determined during a titration. Using a calibrated burette to add the titrant, it is possible to determine the exact amount that has been consumed when the endpoint of titration is reached. The endpoint is where the titration is complete, as determined by an indicator (see below). At the titration endpoint, the quantity of reactant in the titrant added during the titration is stoichiometrically equivalent to the quantity of reactant in the analyte. This is ideally the same volume as the equivalence point – the volume of added titrant at which the number of moles of titrant (nT) is equal to the number of moles of analyte (nA), is in stoichiometric ratio of the given chemical reaction. Titrations can be classified by the type of reaction. Different types of titration reaction include acid-base titrations, complexometric titrations, etc. Within practicals from physical chemistry we will deal with acid-base titrations. Acid-base titrations are based on the neutralization reaction between the analyte and an acidic or basic titrant. In volumetric analysis we can use a pH-indicator to detect the endpoint of the reaction. Neutralization is a chemical reaction, also called a water forming reaction, in which an acid and a base or alkali (soluble base) react and produce a salt and water:

acid + base → salt + water

For example, the reaction between hydrochloric acid and sodium hydroxide solutions:

hydrochlorid acid + sodium hydroxide → sodium chloride + water

$HCl + NaOH \rightarrow NaCl + H_{2O}$

Before starting the titration a suitable pH indicator must be chosen. The endpoint of the reaction, when all the products have reacted, will have a pH dependent on the relative strengths of the acids and bases.
The pH of the endpoint can be roughly determined using the following rules:

- A strong acid reacts with a strong base to form a neutral (pH=7) solution;
- A strong base reacts with a strong acid to form a neutral (pH=7) solution;
- A strong acid reacts with a weak base to form an acidic (pH<7) solution;
- A strong base reacts with a weak acid to form an acidic (pH>7) solution.

When a weak acid reacts with a weak base, the endpoint solution will be basic if the base is stronger and acidic if the acid is stronger.If both are of equal strength, then the endpoint pH will be neutral. Frequently, during a titration it is also useful to monitor the progress of the titration with a graph. This graph is known as a titration curve. Such a curve reflects the changes in pH that occur as titrant is added from a burette to the analyte in the beaker below the burette. Monoprotic acids contain one acidic hydrogen, for example hydrochloric acid (HCl), nitric acid (HNO_3), acetic acid (CH_3COOH), etc. Titration curve of strong monoprotic acid with strong base is shown in figure 1. pH indicators are generally very complex organic molecules (frequently weak acids or bases). When introduced into a solution, they bind to H+ or OHions. They will contain a structural component that is called a chromophoric group, or chromophore. This group will have a structure that changes slightly when the pH of the system changes. The indicator will have one structure through one range of pH values, and a second structure trough a second range of pH values. When the structure changes, as a response to pH, the chromophore will also change its color. We can titrate weak acids(acetic, succinic, citric) (resp. strong acid HCl) with a strong base (NaOH). We will use phenolphthalein ($C_{20}H_{14}O_4$) – as pH indicator. It is colorless in acidic solutions (pH<8), instead in basic solution (pH>8) its color is violet.

Adapted from: fpharm.uniba.sk

TEACHING AIMS:

- Understanding the meaning of analite;
- Understanding the meaning of titrant;
- Understanding the meaning of pH-indicator;
- Understanding the differences between the different types of titrations;
- Understanding the different method of titration;

EXERCISES (read the text)

1 Read the text and complete the scheme below

	→ is a common laboratory method of quantitative analysis that can be used to determine the unknown concentration of a known reactant
	→ is a solution of the substance whose concentration is unknown and sought in the analysis
	→ is a solution in which the concentration of a solute is precisely known
	→ is the volume of the titrant required to react with a given quantity of an analyte that is precisely determined during a titration. Using a calibrated burette to add the titrant, it is possible to determine the exact amount that has been consumed when the endpoint of titration is reached
	→ the quantity of reactant in the titrant added during the titration is stoichiometrically aquivalent to the quantity of reactant in the analyte
	→ In volumetric analysis we can use it to detect the endpoint of the reaction
	→ is known as a titration curve