

Subject 5. Titrimetric analysis. Method of acid-base titration

1. Importance

Diagnostics of diseases is often based on the data of clinical, biochemical and physico-chemical methods of analysis. Titrimetric analysis is one of the most important methods of chemical analysis. It includes the neutralization method in its two divisions: alkalimetry and acidimetry. The neutralisation method is used for measurement of acidity of gastric juice, urine and other biological fluids, as well as measurement of chlorides in blood plasma. In the sanitary analysis the neutralisation method is used for analysis of drinking water, measurement of acidity of food. The student needs basic understanding of the theory and methods of titrimetric analysis to study biochemistry, pharmacology, hygiene.

Competencies

Capacity for abstract thinking, analysis and synthesis, capacity to learn.

Ability to apply knowledge in practical situations.

Know standard methods of physical and chemical (laboratory and instrumental) studies of biological systems of the human and the environment. Be able to analyze and evaluate results of physicochemical (laboratory and instrumental) studies of biological systems in the organism and the environment. Be responsible for decisions taken on the basis of evaluation of results of physicochemical (laboratory and instrumental) studies of biological systems of the organism and the environment.

Ability to assess and ensure quality of work.

Ability to communicate in native language both orally and in writing.

Use native language in professional and business communications and preparation of documents.

Ability to choose strategy of communication; ability to work in a team; skills of interpersonal interaction.

Ability to exercise healthy life style.

2. Concrete aims

1. Analyze the principles of the titrimetric methods.

2. Analyze concentrations of acids and bases in solutions with methods of acid-base titration.

3. Basic knowledge, skills necessary for studying the subject (interdisciplinary integration)

| Previous subjects | Obtained skills |
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| 1. Biological and bioorganic chemistry | Use theories of acids and bases; know formulas, names and properties of acids and bases. Write molecular formula of acetic acid. Understand acidity and basicity. |
| 2. Ukrainian language for professional purposes | Have perfect knowledge of the native language. Be able to communicate in the native language both orally and in writing. Use native language in professional and business |

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| 3. Foreign language for professional purposes | communications and preparation of documents. Possess basic knowledge of foreign languages. Be able to communicate in a foreign language. |
| 4. Latin language and medical terminology | Use a foreign language in professional activity. Master medical terminology in Latin language. |

4. Tasks for independent work during preparation for the class and in class.

4.1. The list of key terms, parameters, characteristics which the student is to learn while preparing for classes:

| Term | Definition |
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| 1. Titrimetric analysis. | Titrimetric analysis is a method where amount of a substance is found with the volume of a reactant of exact concentration used for a reaction with a certain volume of a solution of the analyzed substance. |
| 2. Classification of titration methods. | Classification by the reaction type (most important classification): 1. Acid-base titration (neutralization). 2. Redox titration (oxydometry). 3. Complexonometry. 4. Precipitation. |
| 3. Method of acid-base titration. | The method is based on the neutralization reaction, that is an acid-base interaction between the analyte and the titrant. |
| 4. Acid-base indicators. | Indicators are organic pigments with weak acidic or basic properties that change color depending on pH of the solution. These are phenolphthalein, litmus, methyl orange, methyl red. |

4.2. Theoretical questions for the lesson:

1. Basics of titrimetric analysis. Classification of titration methods.
2. Method of acid-base titration. Applications of the method in medical practice.
3. Acid-base indicators.

4.3. Practical work (task) done by students in class

1. Technique of volumetric analysis

Utmost accuracy is crucial for obtaining correct data. Make sure that you have all necessary clean glassware at hand before you have started. Learn the analysis procedure and prepare your notebook for writing the data.

Filling the burette with work solution.

First rinse the burette with distilled water, then with work solution. Fill the burette with the work solution a bit higher than the mark. Remove the air bubble from the burette by lifting its end slightly and pressing the other end. After the lower end is completely filled with the solution and the funnel is removed make the solution to the zero mark. Pressing the clip, remove excess solution in drops until

the lower part of the meniscus of a colorless solution or the upper part of the meniscus of a colored solution is level with the zero mark. Make sure your eye is level with the meniscus while doing that.

Measuring solutions with pipettes.

Use chemical pipettes to take precise quantity of a necessary solution. First rinse the pipette with the solution. Then fill the pipette with the solution slightly higher than the mark. Quickly close the upper end of the pipette with your forefinger and take the pipette out. Releasing the finger let the excessive solution drop out until the meniscus is level with the mark. Carefully move the pipette to a flask. Hold the pipette vertically and let the solution out. The end of the pipette must not touch the flask. Do not shake the pipette or blow into it to get the rest of the solution out.

A solution to be titrated often contains additional components that create certain medium or react with a certain substance transforming it into a state necessary for the titration. Solutions of those components are also measured with pipettes or measuring cylinders.

Titration procedure

Place a conical flask with a solution to be titrated on white paper under the burette. The burette end must be level with the neck of the flask. Press the clip to let the work solution drop into the flask. Shake the flask continuously to mix the solution. The titration is nearly at end, when the solution in the flask obtains the necessary color in the place where the drops fall. Then add the work solution only by separate drops. Immediately after a steady color change is obtained, cease the titration and determine the used amount of the work solution. Repeat the titration procedure at least three times.

2. Measurement of the mass percent of the acetic acid.

Pipet 10.0 mL acetic acid solution into a 50-100 mL conical flask, add two to three drops of phenol phtalein and titrate from the burette with a work solution of NaOH until pink. Mark on the burette scale the volume of the work solution which was used for the titration. Repeat the titration two more times and calculate the average volume of NaOH used for the titration:

$$V_{\text{average}}(\text{NaOH}) = \frac{V_1 + V_2 + V_3}{3},$$

where V_1 , V_2 , V_3 are volumes of the NaOH solution in the parallel titrations, mL.

Calculation of the mass part of acetic acid:

1. Calculate the normality of acetic acid in the solution:

$$C_f(\text{CH}_3\text{COOH}) = \frac{C_f(\text{NaOH}) \cdot V_{\text{average}}(\text{NaOH})}{V(\text{CH}_3\text{COOH})},$$

where $C_f(\text{NaOH})$ is the molarity of NaOH solution, mol/L,

$V(\text{CH}_3\text{COOH})$ is the volume of the acetic acid that was used for the titration, mL.

2. Calculate the mass of acetic acid in one liter of the solution:

$$m(\text{CH}_3\text{COOH}) = C_f(\text{CH}_3\text{COOH}) \cdot M_f(\text{CH}_3\text{COOH}) \cdot V,$$

where $M_f(\text{CH}_3\text{COOH})$ is the molar mass of equivalent CH_3COOH , g/mol;

$V = 1\text{L}$ – the volume of the acetic acid solution.

3. Calculate the mass part of acetic acid in the weighed portion of concentrated acetic acid that had been used for preparation of 1L of the analyzed solution.

$$\omega(\text{CH}_3\text{COOH}) = \frac{m(\text{CH}_3\text{COOH}) \cdot 100\%}{m(\text{weighed portion})}.$$

3. *Writing a report of the laboratory work:*

Write down the calculation in the notebook, make conclusions.

Contents of the subject (abstract):

1. Basics of titrimetric analysis. Classification of titration methods.

Titrimetric analysis is a method where amount of a substance is found with the volume of a reactant of exact concentration used for a reaction with a certain volume of a solution of the analyzed substance.

Classification by the reaction type (most important classification):

1. Acid-base titration (neutralization).
2. Redox titration (oxydometry).
3. Complexonometry.
4. Precipitation.

2. Method of acid-base titration. Applications of the method in medical practice.

The method is based on the **neutralization** reaction that is an acid-base interaction between the analyte and the titrant. The neutralisation method is used for measurement of acidity of gastric juice, urine and other biological fluids, as well as measurement of chlorides in blood plasma. In the sanitary analysis the neutralisation method is used for analysis of drinking water, measurement of acidity of food.

3. Acid-base indicators

Indicators are organic pigments with weak acidic or basic properties that change color depending on pH of the solution. These are phenolphthalein, litmus, methyl orange, methyl red.

Materials for self control:

A. Tasks for self control:

1. Select the group of substances, amount of which can be measured with alkalimetry.

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| a) HCl , NaOH , K_2CO_3 ; | c) KOH , NH_3 , CaSO_4 ; |
| b) HCl , CH_3COOH , NaHCO_3 ; | d) $(\text{NH}_4)_2\text{SO}_4$, NH_4Cl , NaCl . |

2. Select an indicator for a measurement of concentration of a strong acid in a solution with an alkalimetric titration (color change intervals are given in brackets).

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| a) phenolphthalein (8.2 - 10.0); | c) litmus (4.4 – 6.4); |
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- b) methyl orange (3.1 - 4.4); d) methyl red (4.4 – 6.2).
3. Select an indicator for measurement of the substances that create weak acidity of biological liquids, if the leap on the alkalimetric titration curve was 7.8 – 10.9 pH (intervals of indicator color change are given in brackets).
- a) phenolphthalein (8.2 - 10.0); c) methyl red (4.4 – 6.2);
b) methyl orange (3.1 - 4.4); d) naphthylphthalein (7.4 – 8.6).
4. Select a group of acids which are used as work solutions in acidimetry.
- a) HCl, H₂SO₄, CH₃COOH; c) H₃PO₄, H₂S, H₃BO₃;
b) CH₃COOH, H₂C₂O₄, H₃PO₄; d) HCl, HNO₃, H₂SO₄.

B. Calculation tasks for self control:

1. 25.05 mL 0.1244 N HCl solution was titrated against 25.0 mL NH₃ solution. Calculate the mass of NH₃ in 1 liter of the solution.

Literature

Main:

1. Medical Chemistry: textbook / V.O. Kalibabchuk, V.I. Halynska, V.I. Hryshchenko et al.; edited by Prof. V.O. Kalibabchuk – Kyiv: “Medicine”, 2010 – 224 p. (P. 70 – 80).

Informational resources:

2. www.pdmu.edu.ua
<https://med-chemistry.pdmu.edu.ua/>

(Web page of Poltava State Medical University).