МІНІСТЕРСТВО ОХОРОНИ ЗДОРОВ’Я УКРАЇНИ
ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ МЕДИЧНИЙ УНІВЕРСИТЕТ

FUNDAMENTALS OF TITRIMETRIC ANALYSIS. PREPARATION AND STANDARDIZATION OF NAOH OPERATING SOLUTION

Methodical instructions for 1st year students’ self-work
in Medical Chemistry

ОСНОВИ ТИТРИМЕТРИЧНОГО АНАЛІЗУ. ПРИГОТУВАННЯ ТА СТАНДАРТИЗАЦІЯ РОБОЧОГО РОЗЧИНУ NAOH

Методичні вказівки для самостійної роботи студентів 1-го курсу
з медичної хімії

Затверджено
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Fundamentals of titrimetric analysis. Preparation and standardization of NaOH operating solution: methodical instructions for 1st year students' self-work in Medical Chemistry / compiled by A.O. Syrovaya, T.S. Tishakova, E.V. Savelieva et al. – Kharkiv: KhNMU, 2017. – 24 p.

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Основи титриметричного аналізу. Приготування та стандартизація робочого розчину NaOH; методичні вказівки для самостійної роботи студентів 1-го курсу з медичної хімії / уклад. Г. О. Сирова, Т.С. Тішакова, О.В. Савельєва та ін. – Харків: ХНМУ, 2017 – 19 с.

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Subject «Fundamentals of titrimetric analysis. Preparation and standardization of NaOH operating solution»

1. **Number of hours 4**
2. **Material and methodological support.**

Posters:

1.Graph structure of the subject.
2. Law of equivalents
3. Main concepts of titrimetric analysis
4. Titration curves
5. Most common acid-base indicators
6. Laboratory glassware used in titrimetric analysis
7. Operation technique with pipettes
8. Instructions for use of glassware

Multimedia support: presentations, scientific films.

Laboratory glassware and reagents for performing of laboratory works: «Neutralization method. Standardization of NaOH», «Gastric juice aicidity determination», «Tap water hardness determination» (stand rods, burettes, solutions of NaOH, $H_2C_2O_4 \cdot 2H_2O$, solution of gastric juice with different acidity, B Trilon solution, ammonia buffer, indicators: methyl orange, phenolphtalein, chromogen black).

Educational literature

1. Medical chemistry / V.A. Kalibabchuk, V.I. Halynska, V.I. Hryshchenko et al.; – Kyiv:AUS Medicine Publishing, 2010, - 224 p.
2. Fundamentals of medical chemistry: manual for students' self-work / A.O. Syrovaya, E.R. Grabovetskaya, L.G. Shapoval. – Kharkiv: KhNMU, 2015.–196 p.
3. Medical chemistry. Adapted concise course: manual for students' self-work / A.O. Syrovaya, E.R. Grabovetskaya, L.G. Shapoval. - Kharkiv: KhNMU, 2013. – 160 p.

4. Medical chemistry: workbook for self-work of first-year students of medical and dentistry faculties / compiled by A. O. Syrovaya, V. N. Petunina, V. A. Makarov et al. – Kharkiv : KhNMU, 2017. – 72 p.
5. Fundamentals of titrimetric analysis. Preparation and standardization of NaOH operating solution: methodical instructions for 1st year students' self-work in Medical Chemistry / compiled by A.O. Syrovaya, T.S. Tishakova, E.V. Savelieva et al. – Kharkiv: KhNMU, 2017. – 24 p.
6. Individual tasks for students' self-control of knowledge in Medical Chemistry / A.O. Syrovaya, L.G. Shapoval, V.N. Petiunina et al. – Kharkiv: KhNMU, 2014. – 50 p.
7. Text of Lecture.

3. **Substantiation for the subject.** Methods of titrimetric analysis are widely used in medico-biological and hygienic investigations to make the analysis of biological liquids, drinking water and sewage, food, medicines, etc. Knowledge in titrimetric analysis is necessary for a future doctor to solve a large number of scientific and practical questions.

4. **The purpose of the subject:**
- general: to analyze principles of titrimetric methods of analysis
- specific: to analyze quantitative content of substance in the solutions using methods of acid-base titration.

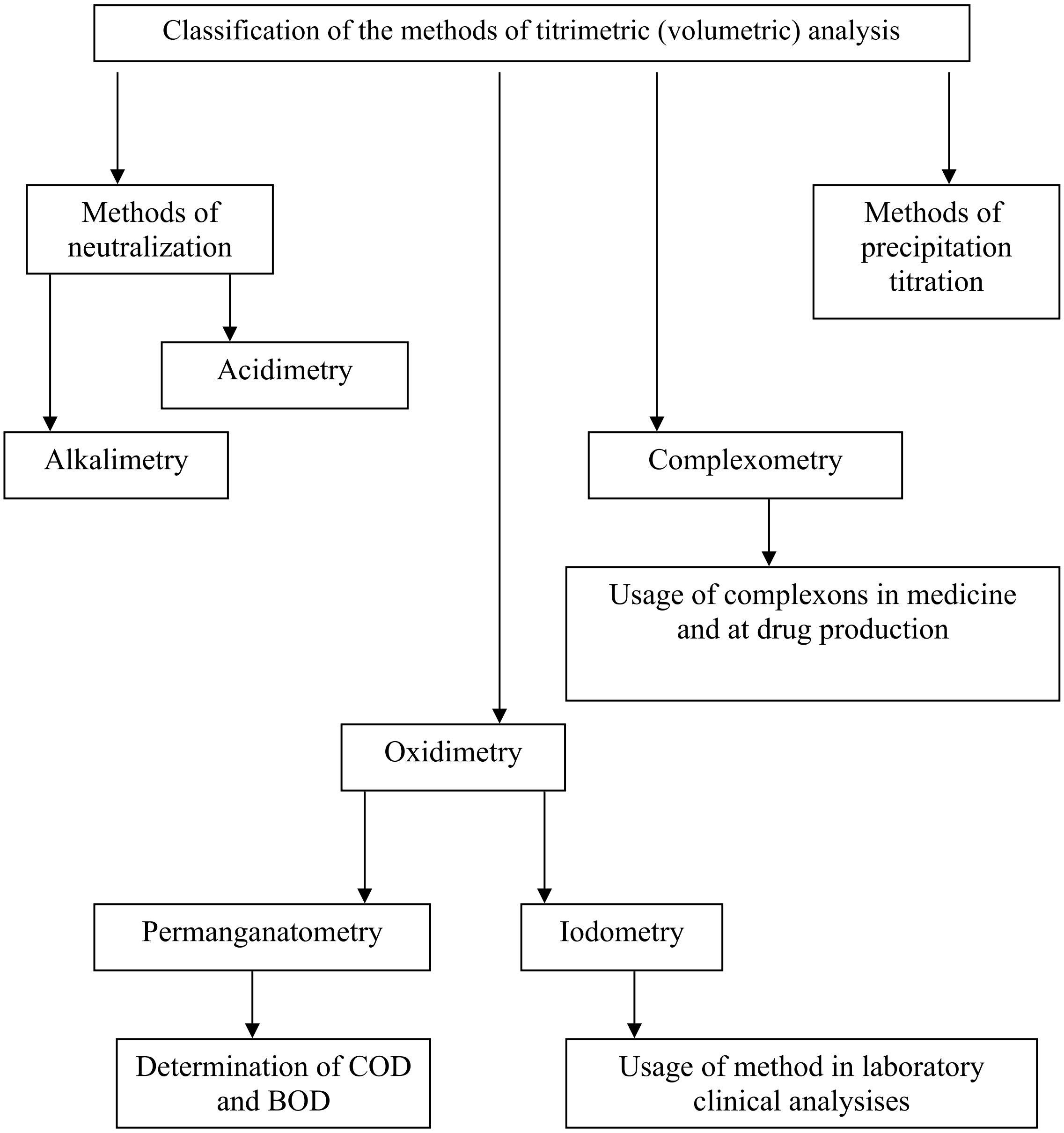
a) **to know:** law of equivalents, the main concepts of volumetric analysis, the requirements for the reactions used in volumetric analysis, classification of the methods of volumetric analysis, the requirements for a standard substance, volumetric glassware used for analysis, titration technique and the determination of the equivalence point.

b) **to be able to:** determine the molar mass of equivalents, write down the law of equivalents for every couple of interacting substances, calculate mass of the substance necessary to prepare a definite volume of operating solution with the given molar concentration of the equivalent, calculate the molar concentration of the equivalent according to the mass of the substance taken in the definite volume, calculate the molar concentration of the equivalent and titer of the investigated solution according to the results of titration, determine the purity of the medicine i.e. the mass percent of active substance in the initial mass or in the solution according to the results of titration.

c) **practical skills:**

- to determine the molar mass of the equivalents;
- to write down the law of equivalents for every couple of interacting substances;
- to calculate mass of the substance necessary to prepare a definite volume of operating solution with the given molar concentration of the equivalent;
- to calculate the molar concentration of the equivalent according to the mass of the substance taken in the definite volume;
- to calculate the molar concentration of the equivalent and titer of the investigated solution according to the results of titration;
- to determine the purity of the medicine i.e. the mass percent of active substance in the initial mass or in the solution according to the results of titration.

5. **Graph structure of the subject.**



6. Plan of students' work.

№	Stages	Time (min.)	Training and visual aids	Location
1.	Motivation description and plan of topics. Questions and answers	25	Manual (work book)	Class room
2.	Incoming control	20		

3.	Independent work of students with methodical literature, the solution of educational problems, filling of work-book	50	Methodical instructions for students, text of lecture, manual for students' self-work, work-book, reference data, tables
4.	Laboratory work	45	Methodical instructions for students, text of lecture, manual for students' self-work, work-book, reference data
5.	Final control	25	
6.	Analysis and conclusions Home work	10 5	

7. **Tasks for self-work:**

- list of questions to be studied:

1. Law of equivalents.
2. Main concepts of volumetric analysis:
    1) Operating solution (titrant);
    2) Investigated solution;
    3) Titration;
    4) Equivalence point;
    5) Acid-base indicators.
3. The requirements for the reactions used in volumetric analysis.
4. Classification of the methods of titrimetric (volumetric) analysis.
    1) Oxidation-reduction methods (the oxidimetry)
        a) Acidimetry;
        b) Alkalimetry;
        c) Titration curves;
        d) Choice of indicators for different cases of titration.
    2) Oxidation-reduction methods (the oxidimetry):
        a) Permanganatometry;

b) Iodometry.

3) Methods of complex analysis (complexonometry)

5. Operating solutions (standard solution and standardized solution).
6. The requirements for a standard substance.
7. Titration technique and the determination of the equivalence point.

1. Law of equivalents

The volumes of the solutions reacting with each other quantitatively are inversely proportional to the molar concentration of the equivalents.

For example, for the reaction $2NaOH + H_2C_2O_4 \leftrightarrow 2H_2O + Na_2C_2O_4$ the law of equivalents is written as follows:

$$V(NaOH) \times C_E(NaOH) = V(H_2C_2O_4) \times C_E(1/2H_2C_2O_4).$$

2. The main concepts of the volumetric analysis:

1) *The operating solution (or the titrant)* is a solution the equivalent's molar concentration C (E) and the titer T of which are exactly known.

Titer is the number of grams of a substance per 1ml of a solution.

$$T = \frac{C(E) \times M(E)}{1000}$$

2) *The investigated solution* is a solution the equivalent's molar concentration and the titer of which should be determined.

3) Titration is a process of addition of one solution with a known concentration to another solution in order to determine the C (E) and the titer of the last. Generally titration is performed by the addition of the solution with known concentration (titrant) until the end of the reaction with a given amount of a substance being determined (the **analyte**).

4) The equivalence point is a titration moment when the mole-equivalents quantity of the operating solution is equal to the mole-equivalents quantity of the investigated solution:

5) *Acid-base indicators.*

Indicators used in acid-base titration are usually weak organic acids or bases, which change colour with pH.

Indicators which have only one coloured form is called one-colour indicator as opposed to two-colour indicators for which two form (acid **HInd** and conjugate base **Ind$^-$)** differ in colour. The color of the solution depends on these forms' concentration ratio. Indicators should have intensive coloration it allows titrated solution would be clearly coloured at low concentrations (10^{-4}—10^{-5} mol/l). A small amount of an indicator is needed. If a large amount of indicator is used, the indicator will affect the final pH, lowering the accuracy of the experiment.

If indicator is weak acid (it is formula represented as **Hind**), then in the solution there are the following equilibria:

$$HInd + H_2O \rightarrow H_3O^+ + Ind^- \text{ or}$$

$$HInd \rightarrow H^+ + Ind^- .$$

At that acid **HInd** and conjugate base **Ind** differ in colour.

$$K_{\text{ind.}} = \frac{[H^+]\cdot[Ind^-]}{[HInd]} .$$

Solving an equation and taking its logarithm we can obtain as follows:

$$pH = pK_{\text{IHnd}} + \lg\frac{[Ind^-]}{[HInd]} .$$

This equation indicates that there are two forms of indicator in the solution upon the condition of any pH: $HInd$ and Ind^-. Coloration of these forms is different and that's why depends on these forms' concentration ratio.

Human eye sees changes of solution's coloration when concentration of one of the coloured form is by 10 times greater than concentration of other form.

There are many known acid-base indicators besides their characteristics differ from each other.

As result of it transition intervals of different indicators cover approximate all pH scale.

Indicators are characterized not only by the pH range of colour change but titration exponent (*pT)*, which is equal *pH* corresponding to the abrupt change of coloration. *pT* value is close to the value of pK indicator:

$$pT \approx \text{pK}_{\text{ind}} \text{ at } [Ind^-] = [HInd] .$$

3. Requirements which must be fulfilled for the reaction in the volumetric analysis:

1) The reaction should be very fast and practically irreversible.

2) The reaction must be simple and well defined i.e., stoichiometric.

3) There should be no complicating side reactions.

4) Reaction should proceed quantitatively, i.e. reaction constant should be high.

5) There should be the method of the equivalence point determination for the reaction.

4. Classification of the methods of the titrimetric (volumetric analysis)

The following methods are used in volumetric analysis:

- neutralization method;
- oxidation-reduction method;
- precipitation method;
- chelatometry method;

1) Methods of acid-base titration.

Neutralization method is based on the reaction of H^+ and OH^- ions interaction with slightly dissociated water molecules forming:

$$H^+ + OH^- \leftrightarrow H_2O$$

Weak electrolyte - water forms and *pH* changes.

Acid-base titration divides by two types of analysis: alkalimetry and acidimetry.

a) **Acidimetry.**

Acidimetry is called an acid-base titration in which a base is titrated with a standard solution of an acid. For example, as titrant can be taken 0.1 M HCl; H_2SO_4 and as standard substances for standardization $Na_2B_4O_7 \cdot 10H_2O$; Na_2CO_3.

Acidimetry is used for determination of strong and weak bases, basic salts which exhibit basic properties.

b) **Alkalimetry**.

Alkalimetry is called an acid-base titration in which an acid is titrated with a standard solution of an alkali (a base). It is used for determination of strong and weak acids, acidic salts which exhibit acidic properties. For example, as titrant can be taken 0.1 M NaOH; KOH and as standard substances - oxalic acid $H_2C_2O_4 \cdot 2H_2O$; succinic acid $H_2C_4O_4$ are used for standardization.

c) *Titration curves.* To choose indicator correctly it is necessary to look at the change of acidity and basicity at different cases during the neutralization process.

The cycle of the acid-base titration can be shown graphically within **pH – volume of titrant** coordinates because the concentration of hydrogen ions in a solution, i.e. its pH, changes in proportion as the operated solution is being added to the investigated one. Such graphical images are called titration curves.

The form of the titration curves depends on the acid and base's strength.

Titration curves differ in pH jump and the pH value near the equivalence point.

A titration of a strong acid with a strong base.

For example, the titration of a solution of HCl C (HCl) = 0.1mol/L against NaOH, C (NaOH) = 0.1mol/L.

Table 1

Concentrations of hydrogen ions

Neutralized acid (%)	$C(H^+)$	pH
0	10^{-1}	1
90.0	10^{-2}	2
99.0	10^{-3}	3
99.9	10^{-4}	4
100	10^{-7}	7
Added excess of NaOH		
0.1	10^{-10}	10
1.0	10^{-11}	11
10.0	10^{-12}	12

From the table 1 we can see that at the beginning of the titration the concentration of hydrogen ions changes slowly and reaches the value 10^{-4} mol/L. In the process of titration pH gradually increases. When 99.9% of acid neutralized then after addition of NaOH pH of the solution abrupt increases. It remains only 0.1% of the titrated acid or 0.1% of NaOH excess is added if there is change of $C(H^+)$ from 10^{-4} mol/L to 10^{-10} mol/L which corresponds to the changing of pH on 6 units. That's why the titration curve is practically perpendicular to absciss axis near the equivalence point. There is abrupt change of pH of the solution near the equivalence point caused by addition of one drop of the operated solution called **titration jump**.

The meaning of the titration jump (or pH jump) is measured by the height of the vertical line of the titration curve. The more the pH jump the more accurate titration is. The equivalence point for the titration of a strong acid with a strong base corresponds to the point of solution neutralization as a salt that isn't exposed to hydrolysis forms, the pH value at the equivalence point is 7. For titration of strong acid with a strong base the equivalence point and the point of solution neutralization coincide.

As we can see from the table 1 in the region when the ratio of indicator forms is 10 times different i.e. $0.1 < \frac{[Ind^-]}{[HInd]} < 10$, the coloration will be transient. This region is called the pH interval of the indicator colour change. It is represented by the following equation:

$$\Delta pH = pK_{\mathrm{ind}} \pm 1.$$

Titration of a weak acid with a strong base.

For example, titration of acetic acid with a solution of NaOH.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O.$$

In this case pH of a solution will increase gradually during the process of neutralization of a weak acid with a strong base. The titration jump is much more less in this case and not abrupt (it is about 3 units of *pH*). A salt undergoing hydrolysis is being formed as a result of titration:

$$CH_3COO^- + H_2O \leftrightarrow CH_3COOH + OH^-$$

OH^- ions are accumulated as a result of hydrolysis, that's why medium of the solution is basic. Titration finishes in basic medium where the equivalence point is. Solution has alkaline reaction. The equivalence point ($pH = 8.87$) does not coincide with the point of neutralization (pH = 7) and is in basic region of *pH*. The *pH* value in the equivalence point can be calculated through the concentration of the operating solution of base and initial concentration of acid.

For such titration phenolphthalein should be used that's why it changes coloration in basic medium at the $pH = 8.2$—10.

A titration of weak base with a strong acid.

A titration of ammonia hydroxide solution with hydrochloric acid can serve the example of such type of titration.

$$NH_3 \cdot H_2O + HCl \leftrightarrow NH_4Cl + H_2O$$

A salt undergoing hydrolysis on cation is being formed as a result of titration:

$$NH_4^+ + H_2O \leftrightarrow NH_3 \cdot H_2O + H^+.$$

Litmus, methyl orange and methyl red can be used as indicator because they change their color at the pH less than 7, in acidic medium. The solution pH decreases with the addition of a strong acid (operating solution). A titration jump is about 3 pH units (it is within the range 4.0 – 6.25). The equivalence point doesn't coincide with the neutrality point as the salt undergoing the cation hydrolysis is being formed as the result of titration; pH value at the equivalence point will be less than 7 (it is near 5.13).

As can be seen from the above at the titration of weak acid (base) the equivalence point is at $pH < 7$, the titration jump is not big and less abrupt.

A titration of strong acid with a strong base.

For example, titration of hydrochloric acid with a solution of NaOH:

$$NaOH + HCl \leftrightarrow NaCl + H_2O.$$

A salt NaCl not undergoing hydrolysis is being formed as a result of titration:

$$Na^+ + Cl^- + H_2O \rightarrow Na^+ + OH^- + H^+ + Cl^-.$$

That's why a reaction of the solution is neutral in equivalence point ($pH = 7$).

In such case indicators with the pH interval from 4 to 10 can be used, for example methyl orange, litmus etc. (acidic) and phenolphtalein (basic). The pH interval of the color change for these indicators coincides with the titration jump on the titration curve.

2) **Oxidation-reduction method (the oxidimetry**).

Respiration and metabolism, photosynthesis and nervous activity of living organisms and others are related to the oxidation-reduction reactions.

Oxidimetry is based on the oxidation-reduction reactions.

Up to date many methods of oxidation-reduction titration have been developed. They are classified according to the operating solution (titrant).

The most widely used methods are:

a) permanganatometry,

b) iodometry.

Solutions of oxidizing agents (for example $KMnO_4$) and reducing agents (for example $FeSO_4$) are used as operating solutions.

There are many oxidation-reduction reactions but for chemical analysis are suitable only reactions which comply the following requirements:

1. The completeness of the reaction process (it should be almost irreversible).
2. The high rate of the reaction process.
3. The absence of the secondary reactions.
4. The existence of the method of the equivalence point determination for the reaction.

a) *Permanganatometry* can be used in clinical analysis for determination of uric acid, calcium, potassium and oxidative enzyme catalase in blood.

In sanitary practice oxidimetry is used for analysis of water where chemical oxygen demand (COD) and biological oxygen demand (BOD) is determined.

COD is a measure of total contamination of water which contains organic and inorganic reducers which react with strong oxidizing agents. Generally it is expressed in moles of equivalents of oxygen consumed per oxidation of impurities with the bichromate:

$$Cr_2O_7^{2-} + 14H^+ + 6\bar{e} \rightarrow 2Cr^{3+} + 7H_2O$$

Residue of bichromate is titrated by the standard solution of iron (II) salt:

$$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ + 6\bar{e} \rightarrow 2Cr^{3+} + 6Fe^{2+} + 7H_2O$$

As COD does not characterize all organic contaminants which can be oxidized to the carbon dioxide and water, to determine total organic carbon organic contaminants are oxidized in severe conditions. Released CO_2 is absorbed by the base.

Unknown index can be found after titration of residue of base with acid. Pollution index of waster water with organic substances is obtained after calculation of COD to total organic carbon ratio.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. Two the same samples should be taken for its determination. Content of dissolved oxygen is determined in first sample. For this purpose solution of Mn (II) salt and ammonia is added to the sample, oxidizing reagent – hydrated form of magnesium oxide forms:

$$O_2 + 2Mn(OH)_2 = 2MnO_2 + 2H_2O$$

Add excess of potassium iodide and released iodine is titrated with a solution of sodium thiosulfate:

$$MnO_2 + 4H^+ + 2I^- \rightarrow Mn^{2+} + I_2 + 2H_2O,$$

$$I_2 + 2Na_2S_2O_3 \rightarrow 2Na + Na_2S_4O_6.$$

Other sample is closed and allow to stay for 2, 3, 5, 10 and 15 days, then find residue of oxygen. Difference between first and second measurements gives BOC.

Permanganatometry is a method of volumetric analysis in which potassium permanganate is used as operated solution.

Permanganatometry is used for the determination of reducing agents by the direct titration with $KMnO_4$. Potassium permanganate does not comply the requirements of standard substances because it has impurities which reduce MnO_4^- to Mn^{2+} with organic impurities presence in distilled water. That's why solution of potassium permanganate is prepared with approximate concentration and standardized with a standard solution of oxalic acid. This method also can be used for oxidizing agents determination. For this purpose back titration is used in which a reducing agent is added to a solution containing the analyte, and the excess reagent remaining after its reaction with the analyte is determined by a titration with $KMnO_4$.

Oxidation with a potassium permanganate can be performed in acidic, neutral and basic medium.

In acidic medium MnO_4^- ion is reduced to the colorless Mn^{2+} ions:

$$MnO_4^- + 5\bar{e} + 8H^+ \rightarrow Mn^{2+} + 4H_2O.$$

In weak acidic medium, neutral and basic MnO_4^- ions reduce to the dark brown precipitate MnO_2:

$$MnO_4^- + 2H_2O + 3\bar{e} \rightarrow MnO_2\downarrow + 4OH^-.$$

Formation of precipitate indicates on the ending of the reaction and in the equivalence point.

In acidic medium MnO_4^- ions color in reddish-violet colors and are reduced in to the colorless Mn^{2+} ions that allows to determine the equivalence point (end of titration).

Discoloration of potassium permanganate proceeds till the consumption of reducing agents. As soon as reducing agent oxidizes (oxidation-reduction reaction finishes), added excessive drop of $KMnO_4$ does not discolor and color solution in light pink colors. That's why at the titration in acidic medium solution of potassium permanganate serves not only as titrant but as indicator.

During the reaction the following reaction takes place:

$$2MnO_4 + 3H_2SO_4 + 5H_2C_2O_4 = 2MnSO_4 + K_2SO_4 + 10CO_2\uparrow + 8H_2O$$

$$\begin{array}{l|l} C_2O_4^{2-} - 2\bar{e} \rightarrow 2CO_2 & 5 \\ MnO_4^- + 8H^+ + 5\bar{e} \rightarrow Mn^{2+} + 4H_2O & 2 \end{array}$$

b) Iodometry is a method of volumetric. Reactions for the method are:

$$I_2^0 + 2\bar{e} \rightarrow 2I^-$$

$$I^- - 2\bar{e} \rightarrow I_2^0$$

This method is used for reducing as well as oxidizing agents determination. Iodometry is used in laboratory-clinical analysis to determine content of glucose in blood, enzyme peroxidase, ascorbic acid.

Iodine solution is used as operating solution in this method.

As iodine is not standard substance its solution is prepared with approximate concentration and standardized. Accurate concentration of this solution can be determined with the titration by sodium thiosulphate.

Starch is taken as indicator in this method because it forms with iodine complex compound of blue color.

During usage of starch as indicator the following requirements shoud be complied:

1. Starch solution should be added at the end of titration when quantity of iodine is small and titrated solution has transparent yellow color.

If starch is added earlier when quantity of iodine is high than formed compound reacts with sodium thiosulphate slowly and solution can be easily over titrated.

2. In such case titration must be performed until color disappears. That's why near the equivalence point solution should be added drop by drop and after addition of every drop it must be mixed. If you don't meet abovementioned requirements you can over titrate solution.

3. Complexonometry.

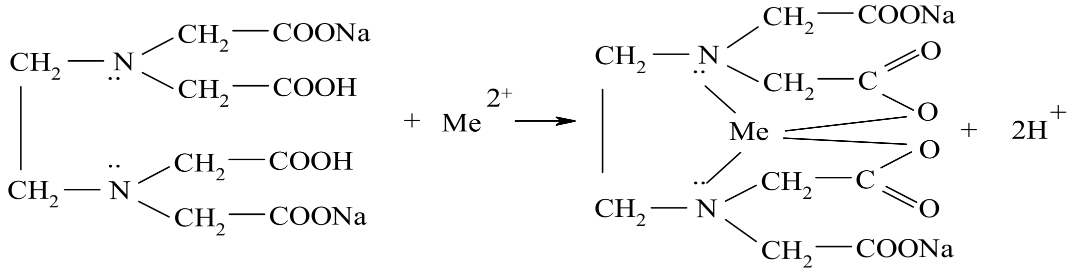
Titrimetric methods based upon complex formation (chelate compounds) between titrant (complexone) and metal ions are used in complexometric analysis to determine metals.

Complexometric method has several advantages:

1. High sensitivity (up to 10^{-3} mol/l).
2. Reactions proceed quickly.
3. It has high selectivity that ensures wide application of this method in chemical analysis.
4. Quick and simple.

The complexometric method of analysis is used to determine the quantity of these ions. It is based on the formation of complex compounds of various metals with the so-called chelates (complexones). Ethylenediaminetetraacetate should be referred to them and is used in the volumetric analysis as the operating solution. The ethylenediaminetetraacetate is often called B trilon. Chemical formula of B trilon is $Na_2C_{10}H_{14}O_8N_2 \cdot 2H_2O$ (M = 372,42 g/mol).

The interaction of B trilon with cations can be expressed by the following equation:

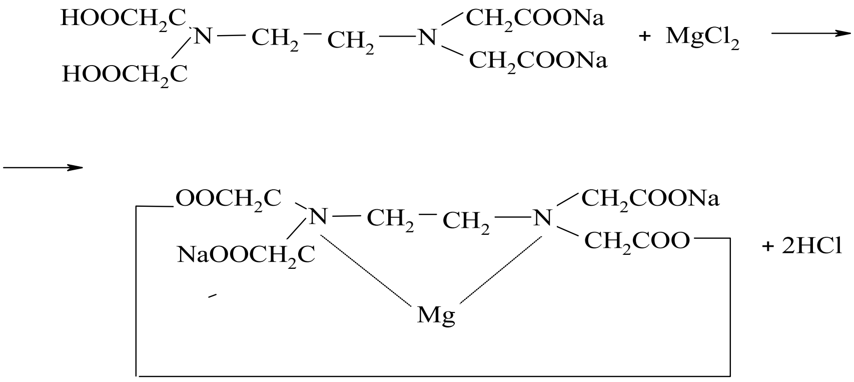


Ions of many metals form hydroxocomplexes in aqueous solutions, these complexes can settle out at a high *pH*. That's why addition of ammonia buffer not only forms certain *pH* but prevents binding of cations with low soluble hydroxides due to formation of ammoniates.

In complexometric titration the equivalence point is determined using metallochrome indicators, which form with titrated ions soluble in water, intensively colored chelates.

For example, let's consider complexometric determination of Mg^{2+} ions, titrated with B trilon (Na_2H_2L) at the presence of ammonia buffer (*pH* = 8—10) and metallochrome indicator — chromogen black (H_3Ind) or murexide.

B trilon forms a strong chelate soluble salts. At that metal replaces hydrogen atoms of carboxyl groups COOH, and forms with nitrogen atoms coordinate bond:



Equation shows that the equivalent of the metal salt is half of that molecular mass, because during the reaction two hydrogen ions are replaced. Prior to titration under the addition of chromogen black part of cations that are in the analyte interact with Mg^{2+} resulting in a formation of chelate complex, which turns the solution pinkish-red color:

$$Mg^{2+} + H_3Ind \rightarrow MgHInd + 2H^+$$

During the titration main reaction between Mg^{2+} and B trilon occur. Colourless chelate forms and coloration of solution retains unchanged:

$$Mg^{2+} + Na_2H_2L \rightarrow Na_2Mg + 2H^+$$

Substitution reaction between chelate complex and B trilon occurs when all free Mg^{2+} ions are titrated:

$$MgHInd + Na_2H_2L \rightarrow H_3Ind + Na_2Mg$$

In this moment of titration coloration of the solution changes abruptly because released indicator paints solution in blue colors.

Thus, in the presence of this indicator content of Mg^{2+} ions in the investigated solution can be determined with high accuracy.

Complex compounds are important for medicine. Medicinal and diagnostic products were developed from complexones among them is B trilon. This complexone is used in medicine due its ability to form in aqueous solutions strong, practically undissociated complexes with many di- and trivalent metals. Such complexes formed in organism are relatively quickly excreted with urine.

5. Operating solutions (standard solution and standardized solution)

a) ***Standard solution*** (a solution with the prepared titer), is a solution which can be prepared with the accurately weighted amount of a standard substance. Generally it is prepared using accurately measured mass of the standard substance or using fixanals are ampoule contain precisely the amount of concentrate necessary for a ready-to-use reagent or buffer solution. It is only necessary to dilute the content of fixanal with the specified quantity of water.

The standard solution for titrimetric analysis should have the following properties:

1. Its concentration should not change during the storage (for several months or years) without repeated standartization.
2. Quick reacts with analyte.
3. Reaction between the reagent and analyte must proceed completely.

4. The substance should react with the investigated solution according to the strict chemical ratio. In practice, this means no adverse reactions between the reagent and analyte.

5. Must be method of determination of the equivalence point in the reaction between the reagent and analyte.

b) *Standardized solution* (a solution with the determined titer) is a solution made of the substances, which are not standard. Standardized solution needes to be further standardized. Its titer and molar concentration of the equivalent is determined according to another standard solution.

6. The requirements for a standard substance

1. The substance should be easily obtained in pure form. Its composition is to be well known and to meet its chemical formulae.

2. The substance should keep stable during the period of storage being in the dry form as well as in the form of solution.

3. A substance should have a high molecular weight; it will enable to minimize the error while weighing the substance during the preparation process.

4. The substance should be readily solved in water.

5. The substance should react with the investigated solution according to the strict chemical ratio. The rate of the reaction should be quite high.

7. Titration technique and the equivalence point determination

1) Fill the burettes (taking the burette readings consider lower meniscus for colourless solutions and upper for colored);

2) Every titration should be started at a zero mark of a burette;

3) The liquid should be slowly poured from the burette as the significant amount of a liquid remains on the burette’s walls and drops down after the end of titration.

4) A solution should change its color near the equivalence point due to a drop of titrant in the process of titration

- list of practical skills to be mastered.

After studying the subject you must be able to determine the molar mass of the equivalents; write down the law of equivalents for every couple of interacting substances; calculate mass of the substance necessary to prepare a definite volume of operating solution with the given molar concentration of the equivalent; calculate the molar concentration of the equivalent according to the mass of the substance taken in the definite volume; to calculate the molar concentration of the equivalent and the titer of the investigated solution according to the results of titration; to determine the purity of the medicine i.e. the mass percent of active substance in the initial mass or in the solution according to the results of titration.

ALGORITHM OF THE LABORATORY WORK

PREPARATION AND STANDARTIZATION OF SODIUM HYDROXIDE OPERATING SOLUTION.

The essence of the procedure.

Acid-base titration method — is one of the methods of volumetric analysis. As NaOH doesn't meet the requirements for standard substances (it's hygroscopic, has admixtures), a prepared solution should be titrated against standard solution. As standard solution in this case oxalic acid may be used. The molar concentration of the equivalent and the titer can be estimated according to the results of titration, i.e. this is the standardization of the operating solution. Phenolphthalein can be used as the indicator:

$$2NaOH + H_2C_2O_4 \rightarrow Na_2C_2O_4 + H_2O$$

The operation process

1. Rinse a clean burette with the operating alkaline solution and then fill it in with the same solution - the lower meniscus must be at zero mark.
2. Pipette 5cm^3 of the standard solution of the oxalic acid to the titration flask. Add two drops of the indicator and rinse the walls of the flask with water.
3. Titrate it against NaOH solution adding it from the burette and mixing constantly up to the moment when light-pink coloration will appear. The volume of NaOH solution used for the titration (V(NaOH)) should be noted down then.
4. The titration process should be carried out till three coincided results will be obtained. The data of the titration should be noted down to the table:

The results of the titration		The results of the calculation
$V(H_2C_2O_4)$, cm^3	$V(NaOH)$, cm^3	
$V_1 = 5{,}00$	$V_1 =$	$C(1/2H_2C_2O_4 \cdot 2H_2O) =$
$V_2 = 5{,}00$	$V_2 =$	$C(NaOH) =$
$V_3 = 5{,}00$	$V_3 =$	$T(NaOH) =$
	$V_{cp} =$	

Mean volume of sodium hydroxide used for the titration is utilized for the determination.

After the experiment make a record of the laboratory work.

The experimental data processing.

1. The calculation of the molar concentration of equivalent of standard solution of oxalic acid,

if there is m = ___________ g in V = ____________ cm^3 of solution, mol/dm^3:

$$C(1/2H_2C_2O_4 \cdot 2H_2O) = \frac{m(1/2H_2C_2O_4 \cdot 2H_2O)}{\text{Ì}\ (1/2H_2C_2O_4 \cdot 2H_2O) \times V(H_2C_2O_4 \cdot 2H_2O)}$$

2. The calculation of the molar concentration of equivalent and the titer of NaOH solution:

$$C(NaOH) \times V(NaOH) = C(1/2H_2C_2O_4 \cdot 2H_2O) \times V(H_2C_2O_4 \cdot 2H_2O)$$

$$C(NaOH) = \frac{C(1/2H_2C_2O_4 \cdot 2H_2O) \times V(H_2C_2O_4 \cdot 2H_2O)}{V_{\text{ñð.}}(NaOH)},$$

$$T(NaOH) = \frac{C(NaOH) \times M(NaOH)}{1000}$$

Conclusions:

8. **Tasks for knowledge control.**

1. Which of the following substances can be used for preparation of standard solution?

A) $H_2C_2O_4 \cdot 2\ H_2O$;

B) NaOH;

C) $KMnO_4$;

D) H_2SO_4;

E) H_2O_2

2. In which case the titration jump is the greatest?

A) titration of a strong acid with a strong base;

B) titration of a strong acid with a weak base;

C) titration of a weak acid with a strong base;

D) titration of a strong base with a weak acid;

E) titration of a weak acid with a weak base.

3. In which case during titration the equivalence point is at pH=7?

A) strong acid+strong base;

B) strong acid+weak base;

C) weak acid+ strong base;

D) strong base+weak acid;

E) weak acid +weak base

4. What is normal pH range of gastric juice?

A) 7,35 – 7,45

B) 1,2 – 3,0

C) 3,0 – 5,4

5. Calculate the mass of $Na_2B_4O_7 \cdot 10\ H_2O$ which is needed to prepare 200 ml of solution with molar concentration of the equivalent 0,1 mol/L.

Reaction proceeds according to the equation:

$$Na_2B_4O_7 + 2HCl + 5H_2O = 4H_3BO_3 + 2NaCl$$

A. 4,8130 г

B. 3,8140 г

C. 2,8111 г

D. 1,8150 г

Answers: 1 - A; 2 - D; 3 - A; 4 – B; 5 - B.

9. **Recommendations for the work results design**

Algorithms for solving educational problems of class work and self-work, and conclusions of laboratory work should be recorded in the workbook.

Навчальне видання

Основи титриметричного аналізу. Приготування та стандартизація робочого розчину NaOH

Методичні вказівки для самостійної роботи студентів 1-го курсу з медичної хімії

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