

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE  
NATIONAL TECHNICAL UNIVERSITY OF UKRAINE  
"IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE"  
Chemical Technology Faculty

## **Guidance**

for course, control and laboratory works on discipline

**«Theoretical Foundations of Chemistry and Technology of Water Preparation.  
Management of Water Resources»**

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE  
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“ \_\_\_\_ ” \_\_\_\_\_2017.

**“The theoretical bases of chemistry and water technology”  
(4/c)**

## **Guidance**

for course, control and laboratory works on discipline

**«Theoretical Foundations of Chemistry and Technology of Water Preparation.  
Management of Water Resources»**

*For bachelors*

in specialty 161 – “*Chemical Technologies and Engineering*”

form of study *full time*

Approved by the methodical commission of

The Chemical Technology Faculty

Minutes “ \_\_\_\_ ” \_\_\_\_\_2017, No. \_\_\_\_

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Guidance for course, control and laboratory works on discipline «Theoretical Foundations of Chemistry and Technology of Water Preparation. Management of Water Resources» for students of the specialty 161 – “Chemical Technologies and Engineering” for preparation of bachelors of the full time form of study is composed in accordance with the Program of academic discipline “The theoretical bases of chemistry and water technology”, and also for students of universities-members of International Projects “Water Harmony II” and “Water Harmony Erasmus+”.

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## INTRODUCTION

Water is source of drinking and industrial supply. All sectors of the economy without exceptions use water in varying amounts. Chemical industry is one of the most polluting sectors of industry. It is a powerful “generator” of contaminated effluent waters, causing reduction or banning of industrial waste waters discharge to water objects. The aim of academic discipline “Theoretical bases of chemistry and technology of water preparation” is clearly knowing not only single elements of water supply system, but interconnection of single stages of water preparation scheme depending on the designation of water, chemical foundation and designing of the processes and methods of water quality improvement for different directions.

### 1. CONTENT OF THE DISCIPLINE

The problem of general rational using of water resources. Recycling water supply systems. The role of chemistry and chemical technology in solving problems of resources of the industrial water supply expansion and in using of protection methods for water objects and environment from contamination.

Water problems. The bases of water resources management. The principals of European System of Natural Waters Monitoring. Normalization of water consumption and disposal.

Characterization of the natural origins of water supply for drinking and industrial aims. Classification of natural water origins. Requirements to water of the different appointment.

Classification and characterization of waste waters by the place of formation. Methods and principles of waste waters canalization. Waste waters treatment plants (WWTP), its appointment. Conditions of waste water disposal into water objects. Legislative acts of Ukraine and other countries of the world about protection of natural water objects and resources.

Natural and waste waters – multicomponent heterogeneous systems. Water as chemical compound. Abnormal properties of water. Models of the liquid water structure. Physical, chemical, biological (bacteriological) indicators of water quality.

The classification of impurities and pollutants of water by its phase and disperse state. Value of the classification designed by L.A. Kulskiy for choosing of alternative methods of impurities removing from water.

Non-reagent methods of water treatment, sphere of its using. Primary water purification. Filtering through grates and screens. Theoretical basics of sedimentation. Stocks equation and its usage for coarse impurities sedimentation process. Hydraulic size and its determination. Equipment of the mechanical methods of water preparation. Constructions and principle of sand traps, oil traps, cyclones, centrifuges, horizontal, vertical, radial and thin layer clarifiers.

Removing of suspended solids from water with filtration, scope. Classification of filters with grain backfilling. Filtering cycle. Requirements to the grain backfilling of filters. The main construction elements and principles of gravity and pressure filters. Clarifiers – accelerators. Double flow filters.

Essence of the flotation method of removing suspended solids and scope. Factors effect on the flotation efficiency. Comparison characteristics of the pressure and vacuum flotation. Typical schemes of the pressure flotation: directly current, partly directly current, recycling. The principle of floaters: impeller, with porous cap, electrical floater, floater of the “Aerofloter” system.

The method of coagulation treatment of water and scope. Physical and chemical basis of water impurities coagulation. Colloidal systems, its structure and properties. Kinetic and aggregative stability of the colloidal systems. Stages of formation and structure of micelle, double electric layer. The main theses of theory of lyophobic sols’ stability. Coagulants used for water treatment and requirements. Coagulant dose and its selection. Flocculants used in water purification processes.

The elements of water purification schemes with coagulation and flocculation: main and secondary equipment, construction features and principle of the flakes formation cells, clarifiers.

The oxidation methods of water disinfection and scope. Chlorination of water: effect of the chlorine compounds on bacteria and microorganisms, mineral and organic impurities of water. Indicators of the water chlorination, chlorine dose and methods of its determination. Chlorine reagents used in processes of water disinfection. Water ozonation: benefits and drawbacks of the method of water disinfection with ozone. The main apparatus equipment of the water disinfection department by the reagent method. Water treatment by ions of noble metals (oligo dynamics). Physical and chemical methods of water disinfection.

Impurities removing from water with solid sorbents. The physical adsorption, sphere of the method using. The dynamics of sorption process: Shilov's model, the initial curves of sorption process. The sorbents used in water preparation process. The methods of sorbents regeneration. The types of schemes and equipment of the adsorption water purification. Adsorbents with immovable, movable and pseudo-liquid layer of sorbent.

Physical and chemical bases and essence of the extraction method of the removing impurities from water, scope. Extraction agents used in water preparation processes and requirements to. The typical extraction schemes. The equipment of the extraction: extraction columns, rotor disk extractor. The methods of the extraction agent regeneration.

The biochemical water purification. The essence and scope of biochemical methods of water purification. The methods of biochemical purification. Characteristics of the active sludge and biofilm. The biological oxygen demand (BOD). Requirements to the biochemical water treatment. Natural and artificial plants of the biochemical purification. The construction features and hydrodynamic regime of the air tanks and bio filters working. The main components of the principle technological scheme of the biochemical water purification. The main theses of the anaerobically treatment of water and sediments. The construction features of the methane tanks.

The classification of the water softening and desalting methods. The essence and scope of the thermal method. The reagent methods: physical and chemical bases, reagents used in water treatment process and comparison characteristics. The apparatus equipment of reagent water treatment departments.

The theoretical bases and scope of the ion exchange method. The brands of ion exchangers, structure and properties. Chemistry and equilibrium of the ion exchange reactions. The dynamics of ion exchange process. The typical schemes of water softening and desalting with the ion exchange method. The principle and construction features of the ion exchange and mixed performance filters. The ion exchangers regeneration. The reagents used in regeneration processes.

The essence and scope of other methods of the water purification: distillation, reverse osmosis, electrical dialysis. The comparison technical and economical characteristics of the water desalting methods.

## **2. TASKS AND RECOMMENDATIONS FOR MAKING COURSE AND CONTROL WORKS**

### **2.1 Tasks for course and control work**

For design, the technology scheme of water preparation according to source and composition of the input water and requirements to the quality of purified water (acc. to the app. 1); to construct and to calculate of the main apparatus of scheme.

The structure of the course work is following:

1. The introduction.
2. The characteristics of water and requirements to purified water.

3. The characteristics of impurities need to be removed from water by its phase and disperse state.
4. The selection of the water purification methods from the specified impurities.
5. The theoretical bases of water purification methods selected for certain scheme.
6. The principal technology scheme of the water preparation.
7. The selection, the main construction elements and calculation of the main apparatus of the scheme.
8. Conclusions.
9. References.

## **2.2 The recommendations for making course and control works**

Firstly, it's necessary to determine what indicators of the water quality are changing during the purification. For this it's necessary to compare its values for the input and purified water (apps. 2, 3). Further it's necessary to determine what impurities cause changes of the indicators of water quality during the purification and to what groups according to the Kulskiy's classification those impurities belong (the app. 5). The essence of its purification methods can be determined by the belonging of impurities to one or another group.

In three first sections of course or control work according to the task it's necessary to present the characteristics of phase and disperse state of all groups of impurities in water. Herewith, it's necessary to pay attention to characteristic signs and properties cause using appropriate purification methods. So, for example, the possibility of removing from water high dispersed suspended particles of the first group (particle size with more than  $10^{-5}$  cm) by sedimentation determined by their kinetic instability in water environments. Moreover, large particles deposited rapidly under the influence of gravitation powers.

When the characteristics and group of the removed impurities are determined, it's possible to select the methods of their removing. These requires, first of all, to become acquainted with methods of the removing of some group of impurities and to conduct the comparative analysis of their spheres of use and purification degree achieved with their helping. For example, the organic substances cause water oxidation, chemical oxygen demand (COD) can be removed from water by the different methods: oxidation, adsorption, extraction, evaporation etc.

Depending on the nature of organic substances, their properties and concentrations in the input and purified water one from the mentioned methods can be selected considering economical and technical indicators. According to their nature, the organic substances can be removed by adsorption or extraction (at their concentration in water less than 1 – 2 g/L). The adsorption method is more relevant. If the content of impurities is bigger, it's economically to use the extraction. Two of these methods belong to regenerative, because they keep to utilize substances removed from water thus decreasing the purification cost. This aspect must be included necessarily, selecting the method. The chemical and biological purification are destruction methods during which the substances are destroyed and can't be utilized. These methods are used if water contents different kinds of substances simultaneously, the utilization is complicated or economically inexpedient.

In the fourth section its necessary to justify selection of the alternative methods for every group of the removing impurities.

For the determination of different factors of water purification effectiveness by any method and optimal conditions choosing of their implementation on practice, it's necessary to study and analyze theoretical basics of processes that occur. So, the disperse impurities of second group are colloidal particles which can be removed from water with coagulants.

The colloidal systems by physical and chemical properties, namely thanks to availability like charge of the particles, are aggregately stable. During water purification from such pollutants the main task is a destruction of the colloidal system, providing rapid coagulation of the dispersion

phase and its separation from the dispersion environment. Knowledge of the physical nature of powers which taken place in the case of the colloidal particles, the roles of different parameters in providing the stability of the colloidal system. Determination conditions of their destruction and the optimal conditions selection of process. The coagulation of colloidal solutions can be caused by adding of the electrolyte. That's why, one of the most important factors in the water purification process by the coagulation is pH of the environment.

Statement of the theoretical bases must be relevant: it must promote of the foundation conditions and optimal parameters of the water purification process.

The next stage of making the course or control work is a design of the technology scheme of water preparation or wastes disposal. During the process of water purification, it's usually necessary to remove impurities of the different groups. That's why, the methods selected for every group of the impurities must be used in certain sequence and provide the preset quality of purification. Herewith, it's necessary to use rule: the sequence of purification from simple to complex, that is removed firstly the impurities of first group, further – the second etc. To ensure correctness of the designed scheme, it's necessary to follow changes of water content by every group of the impurities during every purification stage. The previous stage must always provide the water quality, allowable for its purification at the next stage. For example, the content of hovering substances in water inputs to the aero tank, should not achieve more than 150 mg/L. To this point it's necessary to make the mechanical water purification.

The sixth section contents the description and graphical view of technical scheme; every stage presented as the contours of corresponding apparatus or facilities. It's shown in picture by arrows the direction of material flows: purified water, reagents, the ways of impurities removal.

In the sevenths section it's necessary to note the type and purpose of selected apparatus and facilities which are used for water purification. The equipment is selected according to purified water flow rate, the character and concentration of impurities, and also the degree of purification. The section finished by calculation of the apparatus of the main purification stage. In this section it's necessary to present the sketch of calculated apparatus Further the conclusions and the list of recommended literature is presented.

The estimated amount of the explanatory note is 20 – 25 pages for the course work, 8 – 10 pages for the control work.

### **3. METHODIC RECOMMENDATIONS FOR MAKING OF LABORATORY WORKS**

The aim of laboratory practice of the course “Theoretical bases of chemistry and water preparation technology” is to learn the main indicators of water quality, methods and methodics of the determination some of them: color, smell, alkalinity, acidity, salt content, hardness etc. Besides, the students acquire skills to determine the characteristics of reagents, substances and materials used in water preparation processes, for example, ion volume capacity.

The students should be prepared to the classes on the topic of the laboratory work and to have written protocol. It's necessary to obtain permissions to make the work at the beginning of the classes. Student defends the work by answering to the control questions after work completion and finalizing of the notes.

#### **3.1 Laboratory work 1. Evaluation of the water quality physic indicators**

*The aim of work* is to learn the standard methods of the determination of color, smell, temperature of water.

### *The theoretical theses*

The physic indicators of water quality are temperature, color, smell, flavor, transparency or turbidity.

The color of nature waters, first of all, is caused by availability of humites of iron (salts of humic acids). The water of rivers with the swamp type of nutrition has increased color. The color is evaluated in degrees of the platinum cobalt scale. According to **THE STATE SANITARY NORMS AND RULES 2.2.4-171-10**, it shouldn't exceed 20 degrees (in single cases, by agreement with organs of the sanitary supervision, color is allowed to 30 degrees).

The color is evaluated quantitatively by comparison samples of polluted water with distilled ones. For this purpose, the distilled water poured separately into glassfuls are produced from the transparent glass. If the water isn't colored, it considered transparent. The color is determined quantitatively from the platinum cobalt or dichromate cobalt scale.

The smell of water may be connected with live of water organisms (according to water plants, seaweeds etc.), and also showed up when they die. These are natural smells. The industrial waste waters are discharged to water bodies with impurities of certain smell (phenols, formaldehyde, chlorine derivatives of benzene etc.) These are artificial smells.

First of all, the qualitatively is characterized for water by the smell according to the appropriate signs (fenny, earthy, putrefactive, fish, aromatic etc.). The power of smell is evaluated from the five-mark scale (table 1).

**Table 1. The evaluation of water smell**

Smell	Intensively	Mark
Absent	Not felt	0
Very weak	Only experienced researcher indicates	1
Weak	Consumer indicates, if attention paid	2
Notable	Consumer indicates easily	3
Clear	Strong smell and flavor make water unpleasant for drinking	4
Very strong	Water is unsuitable for drinking	5

The temperature of natural water depends on its origin. The water of underground sources differs constant temperature. The temperature of opened water objects (rivers, lakes) experiences significantly depending on season. For example, the water temperature in Dnipro river (near Kyiv city) changes during the year from 0 °C in winter to 28 °C in summer. Besides, the water temperature can be changed because of decay processes or underground water earning in single places of opened ponds

The optimal temperature for drinking water is 7...11 °C. Water with this temperature has the pleasant taste.

The physic indicators of water quality are so-called organoleptic indicators.

### *The methodic of conducting work*

**Equipment:** volumetric flasks (100 cm<sup>3</sup>) – 15 ones; volumetric flask (500 cm<sup>3</sup>); moderate cylinders (250 cm<sup>3</sup>) – 2 ones; moderate pipette (10 cm<sup>3</sup>); pipette (1 cm<sup>3</sup>); sampler; bulbs – 4 ones; thermometer.

*Reactants:* dichromate cobalt solution; H<sub>2</sub>SO<sub>4</sub> solution (1 cm<sup>3</sup> of acid in 1 L of water); sample of natural and industrial waste waters (students prepare solutions singly).

### ***Experiment 1. The determination of water color by dichromate cobalt scale***

*The preparation of work solution.* K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (0,0438 g) and CoSO<sub>4</sub>·7H<sub>2</sub>O (1 g) are dissolved singly in two vessels in small volume of distilled water. Salt solutions are transferred quantitatively to the volumetric flask (500 cm<sup>3</sup>). Concentrated sulfuric acid is added (0,5 cm<sup>3</sup>) with density  $\rho = 1,84 \text{ g/cm}^3$  and mark is reached by distilled water.

*The preparation of sulfuric acid solution.* The sulfuric acid solution is prepared by mixing 1 cm<sup>3</sup> of concentrated H<sub>2</sub>SO<sub>4</sub> with 1 L of distilled water in the same vessel.

*The preparation of scale.* The main solution is mixed with sulfuric acid solution. The main solution (1 cm<sup>3</sup>) is transferred into the volumetric flask (100 cm<sup>3</sup>) and the mark by sulfuric acid solution is reached. The color of this solution is 5 degrees. For the preparation of solution with color 20 degrees it's necessary to mix 4 cm<sup>3</sup> of the main solution with 96 cm<sup>3</sup> of sulfuric acid solution. For the same methodic to prepare solutions with color 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 degrees.

The control samples of water are compared with the scale. Then their color is determined. Muddy water is filtered in advance.

### ***Experiment 2. The determination of water smell***

The investigated water is poured (2/3 of volume) and shaken off strongly in the bulb with ground glass stopper. Then stopper is opened and the character and intensively of smell is determined. According to **THE STATE SANITARY NORMS AND RULES 2.2.4-171-10**, the intensively of smell shouldn't exceed mark 2 at 20 °C.

### ***Experiment 3. The determination of water temperature***

The temperature of water is determined directly in pond or in water sample. The thermometer is used with the division of the scale 0,1 °C.

The task: to determine the temperature of the tap water and samples proposed by teacher.

#### *The control questions*

1. What indicators of water quality belong to organoleptic?
2. What impurities of water cause its color?
3. What scale the intensively of water smell (flavor) can be evaluated by?
4. What requirements does **THE STATE SANITARY NORMS AND RULES 2.2.4-171-10** provide?

Literature: [1-6]; [17].

## **3.2 Laboratory work 2. The determination of alkalinity, acidity and carbon (IV) oxide content in samples of natural water**

*The aim of work* is to learn the standard methods of evaluation these water quality indicators.

#### *The theoretical theses*

The alkalinity of water from natural origins is caused by weak acid anions and OH<sup>-</sup> ions. The general alkalinity is characterized by the total concentration of ions OH<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, CO<sub>3</sub><sup>-</sup> and anions of other weak acids.

The acidity of natural water with  $\text{pH} > 4,5$  is caused by free carbon (IV) oxide, humic and other weak organic acids; with  $\text{pH} < 4,5$  by strong acids and salts of strong acids and weak bases. It's distinguished the total acidity, free acidity, free carbon (IV) oxide, aggressive carbon (IV) oxide and also acidity independent from other weak non-volatile acids.

### *The methodic of conducting work*

*Equipment:* pipettes ( $100 \text{ cm}^3$ ) – 5 ones; bulbs for the titration ( $250 \text{ cm}^3$ ) – 5 ones; pH-meter.

*Reactants:* chlorine acid solutions – 0,05 M and 0,1 M; sodium hydroxide solution 0,1 M; indicators – methylene orange, phenolphthalein; water samples.

#### **Experiment 1. The determination of general alkalinity of water**

Suspended substances must be removed before the determination of general alkalinity in water. It's necessary to mean, if total alkalinity less than  $0,4 \text{ mmole/L}$ , the determination should be repeated for specification by the titration of water samples by 0,05 M solution of acid. If the color of water is intensive, the titration is conducted or by the pH-meter without indicator, or after water passing through the layer of activated carbon.

One hundred  $\text{cm}^3$  of the sample is titrated by 0,1 M solution of chlorine acid with methylene orange before color transition from yellow to gold-rose. The sample is aerated for increasing the accuracy of the alkalinity determination of water samples in the titration process.

The total alkalinity is calculated by the formula

$$A_{tot} = \frac{C_{HCl} \cdot V_{HCl} \cdot 1000}{V},$$

where  $A_{tot}$  – the total alkalinity of water,  $\text{mmole/L}$ ;  $C_{HCl}$  – acid concentration,  $\text{mole/L}$ ;  $V_{HCl}$  – volume of acid solution spent for the titration,  $\text{cm}^3$ ;  $V$  – volume of the water sample,  $\text{cm}^3$ .

#### **Experiment 2. The determination of total acidity in samples of natural water**

One hundred  $\text{cm}^3$  of water sample are titrated by 0,1 M solution of sodium hydroxide with 5-10 drops of phenolphthalein to the pale pink color.

The total acidity is calculated by the formula

$$Ac_{tot} = \frac{C_{NaOH} \cdot V_1 \cdot 1000}{V},$$

where  $Ac_{tot}$  – the total acidity,  $\text{mmole/L}$ ;  $C_{NaOH}$  – the concentration of sodium hydroxide,  $\text{mole/L}$ ;  $V_1$  – volume of NaOH solution spent for the titration,  $\text{cm}^3$ ;  $V$  – volume of the water sample,  $\text{cm}^3$ .

#### **Experiment 3. The determination of free acidity in natural water samples**

The investigated water ( $100 \text{ cm}^3$ ) is titrated by 0,1 M solution of sodium hydroxide with 3 drops of methylene orange to the yellow color. If the sample of solution becomes yellow after adding the indicator, the free acidity is zero.

The free acidity is calculated by the formula

$$Ac_{free} = \frac{C_{NaOH} \cdot V_2 \cdot 1000}{V},$$

where  $Ac_{free}$  – the free acidity, mmole/L;  $C_{NaOH}$  – the concentration of sodium hydroxide, mole/L;  $V_2$  – volume of NaOH solution spent for the titration, cm<sup>3</sup>;  $V$  – volume of the water sample, cm<sup>3</sup>.

It's necessary to mean that muddy and color of the water prevent the titration. These waters are titrated without indicator. So, the equivalence point of titration is determined by the pH-meter.

#### ***Experiment 4. The determination of acidity in samples, independently of weak non-volatile acids***

The sample of investigated water (100 cm<sup>3</sup>), neutral for the methylene orange, is boiled during two hours for the removing of free carbon (IV) oxide, cooled rapidly and titrated by 0,1 M solution of sodium hydroxide with 5-10 drops of the phenolphthalein to the resistant rose color appearance.

The acidity, caused by weak acids, is calculated by the formula

$$Ac_{weak} = \frac{C_{NaOH} \cdot V_3 \cdot 1000}{V},$$

where  $Ac_{weak}$  – the acidity, caused by weak acids, mmole/L;  $C_{NaOH}$  – the concentration of sodium hydroxide, mole/L;  $V_3$  – volume of NaOH solution spent for the titration, cm<sup>3</sup>;  $V$  – volume of the water sample, cm<sup>3</sup>.

#### ***Experiment 5. The determination of content of free carbon acid in natural water***

The investigated water (100 cm<sup>3</sup>) is titrated by 0,1 M solution of sodium hydroxide with 10 drops of the phenolphthalein to the color, which is resist during 2-3 minutes. The solution of hydroxide is added by little portions by closing the bulb every time and good mixing of its content. The determination is repeated by infusing almost all volume of sodium hydroxide solution at once, founding during the first determination, after the first analysis.

The content of free carbon (IV) oxide is calculated by the formula

$$C_{CO_2(free)} = 44 \left( \frac{C_{NaOH} \cdot V_4 \cdot 1000}{V} - Ac_{weak} - Ac_{free} \right),$$

where  $C_{CO_2(free)}$  – the content of free carbonic acid, mg/L; 44 – the molar weight of carbon (IV) oxide, g/mole;  $C_{NaOH}$  – the concentration of sodium hydroxide, mole/L;  $V_4$  – volume of NaOH solution spent for the titration, cm<sup>3</sup>;  $V$  – volume of water sample, cm<sup>3</sup>;  $Ac_{free}$  – free acidity, mmole/L;  $Ac_{weak}$  – acidity is caused by weak acids, mmole/L.

#### ***Experiment 6. The determination of the content of free carbon acid in natural water***

The content of free and aggressive carbon (IV) oxide is usually small in surface natural water. This indicator has important value for the characterization of natural waters.

For the determination of free carbonic acid, it's possible to use the special nomogram (pic. 1). Previously it's necessary to determine the temperature of water, total salt content (TSC) in it, total alkalinity and pH.

Connecting by the line on scales 1 and 3 lines, responded by the temperature values and TSC (P), the point of crossing line with “dumbly” scale 2 is noted. This point is connected with alkalinity value on scale 4, and the point of crossing line with scale 3 is noted. The point connects with the respectively pH value on scale 5. The continuing of line is determined mark responded the concentration of free carbonic acid to crossing with scale 6.

### ***Experiment 7. The determination of aggressive carbonic acid in natural water***

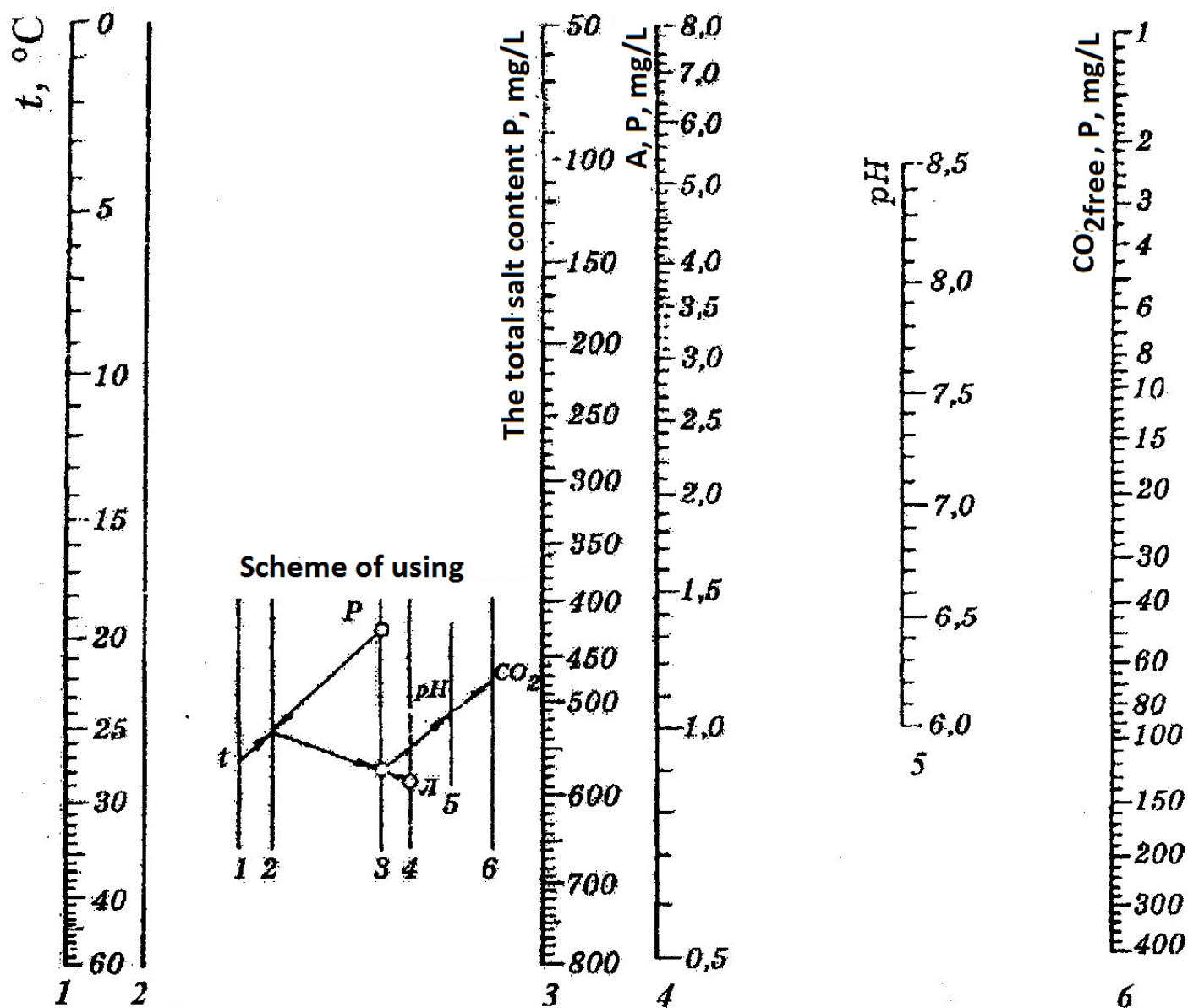
This determination is conducted using nomograms presented in pics. 2 and 3.

The accessory parameter A can be found by pic. 2, having results of water chemical analysis. For this it's necessary to connect points responded by the temperature values and TSC and to find mark on "dumbly" scale 4. The concentration on crossing with scale 3 gives accessory parameter A, connecting it with point responded by calcium ions. The point 1 is found by pic. 3 satisfied these parameters, knowing the content of free carbonic acid (from previously experiment) and alkalinity of analyzed water. If this point is situated above curve responded the accessory parameter A, the water contains aggressive carbonic acid. If below, water doesn't content aggressive carbonic acid.

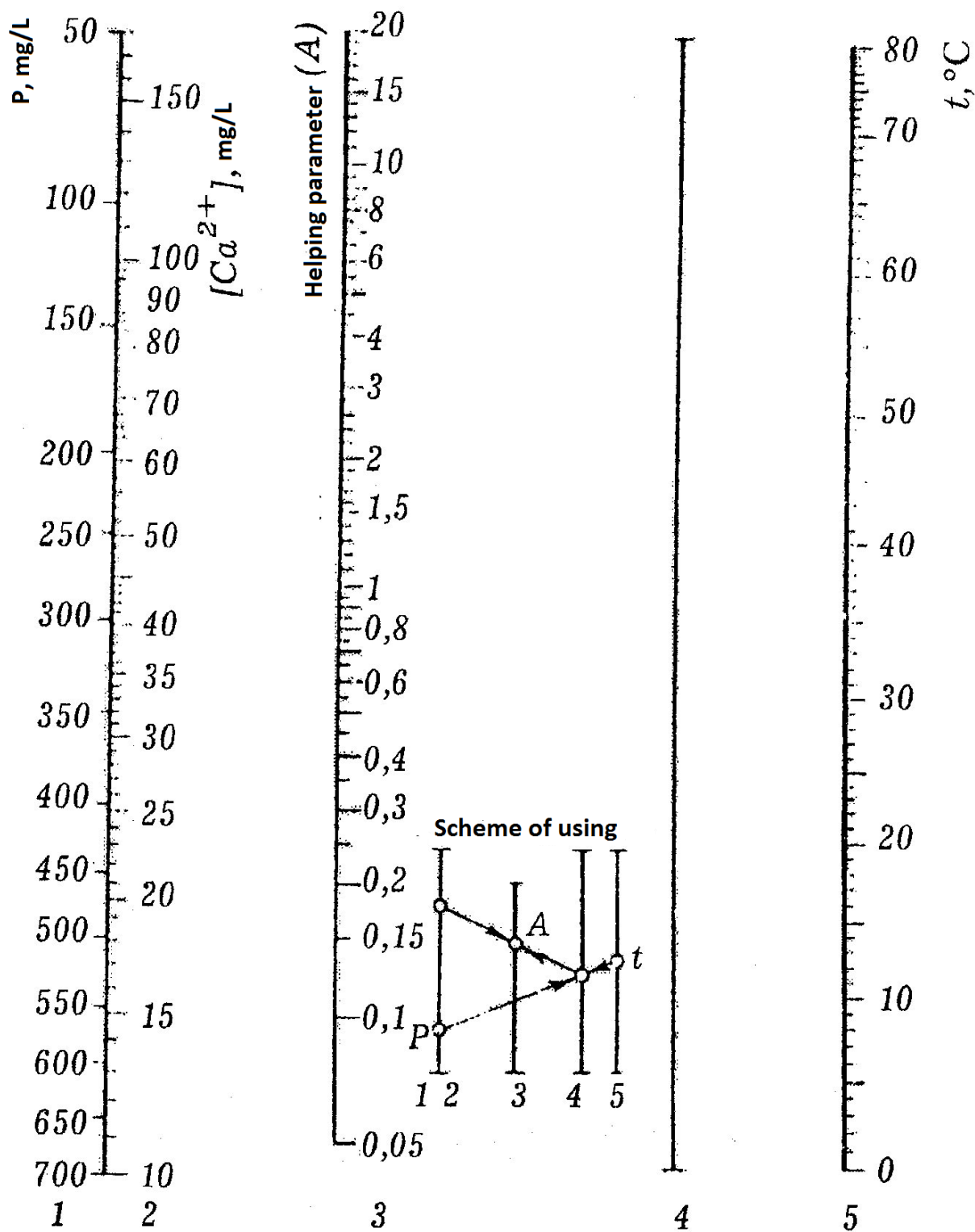
The concentration of free carbonic acid is determined by letting down line from the point 1 parallel by sloping lines. The crossing of this line with curve responds the accessory parameter A. This parameter gives the point 2, responded by the equilibrium concentration of carbonic acid:

$$C_{CO2(agr)} = C_{CO2(free)} - C_{CO2(eq)},$$

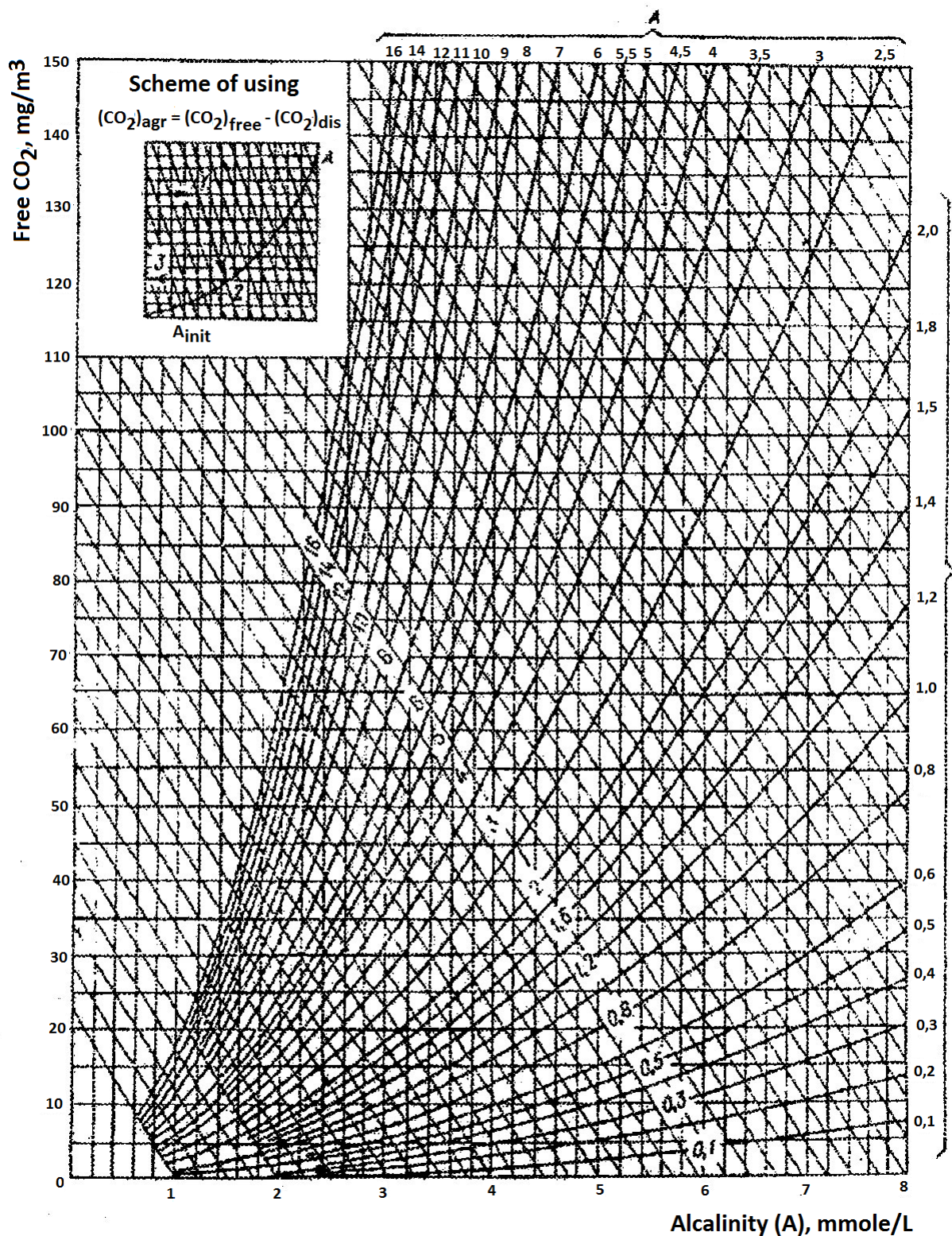
where  $C_{CO2(agr)}$ ,  $C_{CO2(free)}$ ,  $C_{CO2(eq)}$  – the concentrations of aggressive, free and equilibrium carbonic acid, mg/L.



Pic. 1. Nomogram for the determination of the concentration of free carbon (IV) oxide in water



Pic. 2. Nomogram of the determination of helping factor for the calculation of the concentration of aggressive carbon (IV) oxide in water



Pic. 3. Nomogram of the determination of the concentration of aggressive carbon (IV) oxide in water

#### *The control questions*

1. What substances cause the alkalinity of water?
2. What kinds of acidity can be distinguished in natural water?
3. What substances cause availability of free and aggressive carbon acid in water?
4. What is the active water reaction?

Literature: [1-8]; [17].

### 3.3 Laboratory work 3. Dry residue, losses at calcination and oxidation in samples of natural water

The aim of work is to learn standard methods of the evaluation of salt content and organic substances content in natural origins of water supply.

#### *The theoretical theses*

The quantity of salts, dissolved in natural waters, can be determined by dry residue and losses at calcination. The dry residue is formed at evaporation of some water volume, filtrated previously through the paper filter. This filter consists of mineral salts and non-volatile organic substances. The organic part of dry residue of water is determined by residue losses at calcination process. The data about organic substances content in investigated water can be increased (for waters with increased content of salts). Especially, if salts contain nitrogen, and also carbonates, chlorides, crystal hydrates etc. The water is considered fresh, if it usually contents to 1000 mg/L of dissolved salts.

#### *The methodic of work*

*Equipment:* water bath; porcelain cups; conic bulbs; pipettes; paper filters; funnels; burettes; analytic balances; dry wardrobe; muffle furnace; desiccator.

*Reactants:* sulfuric acid solution (1:2) (one volume of  $\text{H}_2\text{SO}_4$  96 % mas. and two volumes of distilled water); 0,01 M solution of potassium permanganate; 0,01 M solution of oxalate acid.

#### **Experiment 1. The determination of dry residue in samples of natural water**

This determination is usually conducted in a day of picking the sample. Water is filtrated through the paper filter. Porcelain cup is dried to the constant mass, cooled and weighed on analytical balances. Filtrated water is evaporated on water bath, filled by distilled water (100 – 150  $\text{cm}^3$ ). The cup with dry residue is dried at 100 – 150  $^{\circ}\text{C}$  to the constant mass, cooled and weighed.

The content of dry residue is calculated by the formula:

$$X = \frac{(m_1 - m) \cdot 100}{V},$$

where  $X$  – the content of dry residue, mg/L;  $m$  – the mass of cup, mg;  $m_1$  – the mass of cup with dry residue, mg;  $V$  – volume of water sample,  $\text{cm}^3$ .

#### **Experiment 2. The determination of losses at the calcination of dry residue**

For the determination of this losses, the dry residue, obtained in previously experiment, is calcined in muffle furnace at the temperature 600  $^{\circ}\text{C}$  during 1 hour, cooled in desiccator and the cup weighed on analytic balances. Losses are calculated by the formula:

$$X_1 = \frac{(m_2 - m) \cdot 100}{V},$$

where  $X_1$  – the content of calcined sample, characterizing mineral impurities in water, mg/L;  $m_2$  – the mass of cup with residue after calcination, mg.

The content of organic part of impurities is found by the formula:

$$X_2 = X - X_1,$$

where  $X_2$  – the content of organic impurities in water sample, mg/L.

### ***Experiment 3. The determination of oxidation in natural water (Kubel's method)***

The water sample (100 cm<sup>3</sup>), picked by pipette or volumetric flask, is poured to conic bulb with glass pellets on the bottom, diluted sulfuric acid (5 cm<sup>3</sup>) and 10 cm<sup>3</sup> of 0,01 M solution of potassium permanganate is added. The bulb must be heat-resistant. The bulb's content is achieved to boiling. It is boiled exactly 10 min. The 0,01 M solution of oxalate acid (10 cm<sup>3</sup>) is added to the bulb with solution. Heated solution is titrated by 0,01 M solution of potassium permanganate to pale pink color. The temperature of the sample shouldn't be less than 80 °C. Then 10 cm<sup>3</sup> of 0,01 M oxalate acid solution is poured to the same bulb to another head liquid and titrated by 0,01 M solution of potassium permanganate. The color shouldn't disappear during one minute.

The oxidation is calculated by the formula:

$$X_3 = \frac{(V_1 - V_2) \cdot 0,08 \cdot 1000}{V},$$

where  $X_3$  – the permanganate oxidation of water, mg of O<sub>2</sub> on 1 L of water;  $V_1$  – total content of 0,01 M potassium permanganate solution, taken for the titration, cm<sup>3</sup>;  $V_2$  – volume of permanganate solution, taken for the titration of oxalate acid (10 cm<sup>3</sup>, the second titration), cm<sup>3</sup>;  $K$  – aliquot coefficient;  $V$  – volume of water sample, cm<sup>3</sup>; 0,08 – oxygen quantity, responding by 1 cm<sup>3</sup> of 0,01 M potassium permanganate solution, mg. (If the calculation of oxidation is in milligrams of the permanganate per 1 L of water, it's necessary to use 0,32 instead of 0,08 – the equivalent of potassium permanganate, responding by 0,01 M solution).

*Attention!* The determination should be repeat, if water sample will become fulvous or transparent during boiling.

### *The control questions*

1. What water indicators characterize dry residue and losses of residue at the calcination?
2. How to determine the content of organic substances in samples of natural water?
3. What total content of salts allows to recommend water for drinking?
4. What indicator of water quality is determined by the Kubel's method?
5. The availability of which impurities in water characterizes the value of permanganate oxidation?

Literature: [1-8]; [17].

## **3.4 Laboratory work 4. Optimal doses of the coagulant**

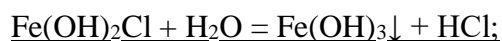
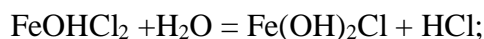
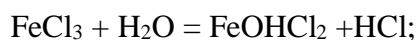
The aim of work is to determine the optimal dose of the coagulant for natural water purification.

### *The theoretical theses*

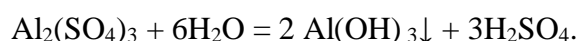
The majority of substances, causing muddy of natural water, are in colloidal state. One of the most effective methods of water purification from colloidal impurities is coagulation. Its essence is in adding of substances-coagulants to water. The sulfates or chlorides of iron or its mixtures are

often used as coagulants. Coagulants are salts of weak bases, hydrolyzed in water, forming colloidal particles of hydroxides. The last ones are adsorbed different impurities of water on its surface. It increases (coagulates) and takes out colloidal and finely dispersed suspended impurities from water.

The hydrolysis of coagulants occurs in stages; its mechanism is enough difficult. Summary, the reactions of hydrolysis, for example, of iron chloride, can be presented by following equations:



The hydrolysis of alumina sulfate occurs the same way:



Some value of the pH responds by each stage of hydrolysis. If the concentration of hydrogen ions in water depends on coagulants overdose, the hydrolysis equilibrium is moved to left. This increases alumina or iron content in water, because of its hydroxide compounds has enough high solubility. Usage of these waters doesn't recommend for drinking water supply (hygiene considerations) and for industrial requirements via possibility of precipitate, forming on the apparatus.

The optimal coagulant dose  $D_{opt}$  is the least. Its dose provides the transparency of purified water 30 cm "by type" according to **THE STATE SANITARY NORMS AND RULES 2.2.4-171-10** for drinking water. If the optimal dose has been selected truth, the purified water doesn't contain alumina or iron. The optimal dose of coagulant depends on many factors. That's why it is determined experimentally by increasing quantity of the coagulant, added to the water.

The passing of coagulation processes significantly depends on type of the coagulant, using in process. If alumina sulfate is used at low temperatures ( $1 - 2^\circ\text{C}$ ), the processes of formation and precipitation of flakes becomes slower. The residual quantity of alumina is accumulated in water, which is the consequence of formation precipitate in ditch water. That's why it's rational to use iron chloride in winter, because the process of formation its flakes is low sensitive to water temperature. Simultaneously, iron chloride has some shortcomings too, for example, after the precipitation of the main mass of big flakes of hydroxide, some quantity of little flakes is in water during a long time. For elimination of this disadvantages, coagulants are used in mixed form. It gives a possibility to save 30 – 60 % of coagulants.

### *The methodic of work*

**Equipment:** volumetric cylinders ( $500 \text{ cm}^3$ ) with stoppers – 7 ones; pipettes (1, 5, 10, 25,  $100 \text{ cm}^3$ ); cylinder with diameter 20 – 25 mm with height not more 350 mm for the determination of water transparency; volumetric flasks (50, 100, 250,  $1000 \text{ cm}^3$ ); text with letters (height 3,5 mm); glass for the sample.

**Reactants:** the solution of alumina sulfate or chloride, samples of polluted water.

### **Experiment 1. The determination of optimal coagulant doses**

For the investigation, the sample of water with knowing transparency had been used. The investigated water ( $400 \text{ cm}^3$ ) is poured to seven cylinders. Then such quantity of the coagulant is

added to cylinders by volumetric pipette (iron sulfate or chloride solution). Its content in water would be 10, 25, 50, 100, 200, 300, 400 mg/L. Water is mixed by three-ones canting of cylinders, closed by stoppers, after adding of the coagulant. The time of entering coagulant into water is noted. After two hours, 250 – 300 cm<sup>3</sup> of clarified water is picked from each cylinder by water pump. It's necessary to pick water carefully for avoiding of muddy of the precipitate. The transparency is established or height of the precipitate layer is measured in samples of the clarified water. The duration of coagulation is determined by teacher.

The time of the beginning of flakes formation, the time of precipitation beginning, height of precipitation layer and height of clarified water pillar are fixed. The type of flakes (loose, big, small) is noted too. The observation is charged every 10 min.

### ***Experiment 2. The determination of water transparency “by the type”***

The water transparency is the edge height of water pillar in centimeters. It is equal the quantity of centimeters, through which it's possible to read the text, written by the standard type (with letters height 3,5 mm).

The investigated water is poured to cylinder with transparent bottom and tap underneath. Cylinder is put on height 4 cm above type. Water is poured through the tap until single words of the text become visible. The height of water layer in cylinder responds the transparency in centimeters.

Input, experimental and calculated data are recorded to tables. Graphics are built in coordinates “water transparency – the dose of the coagulant”, “precipitate layer height – the time of coagulation” or “height of clarified water layer – time of the process”. The optimal dose of the coagulant is determined by the depending “water transparency – the dose of the coagulant”.

**Table 2. Indicators of water purification by the coagulation**

Indicator	Cylinder number						
	1	2	3	4	5	6	7
The type of the coagulant							
The dose of the coagulant, mg/L							
The quantity of the coagulant, cm <sup>3</sup>							
Time of the beginning of formation flakes, min							
Time of the beginning of precipitation flakes, min							
Transparency of purified water, cm							
Optimal dose of the coagulant, mg/L							

**Table 3. The height of layer of the precipitate, mm**

The number of cylinder	The time of process, min								
	10	20	30	40	50	60	70	80	90
1									
2									
3									
...									

**Table 4. The height of layer of clarified water, mm**

The number of cylinder	The time of process, min								
	10	20	30	40	50	60	70	80	90
1									
2									
3									
...									
7									

*The control questions*

1. Explain, what are the principles of water purification by coagulation?
2. Write down equation of the formation of hydroxides at the coagulant solution, added to water.
3. Explain, why the processes of formation and precipitation of flakes of hydroxides become slower at overdosing of coagulant.
4. Define the concepts: water transparency, optimal dose of the coagulant.
5. Explain, why the purified water shouldn't have residual quantities of alumina and iron.
6. Call stages of formation of the micelle.
7. Explain the formation of double electric layer.
8. Give the characterization of the electric kinetic potential.

Literature: [1-8]; [17].

**3.5 Laboratory work 5. The dynamic exchange capacity of cation exchanger**

*The aim of work* is to determine the dynamic exchange capacity of cation exchanger CU-2, until the penetration of  $\text{Ca}^{2+}$  ions into the filtrate. To regenerate cation by the solution of sodium chloride and to wash up it by distilled water.

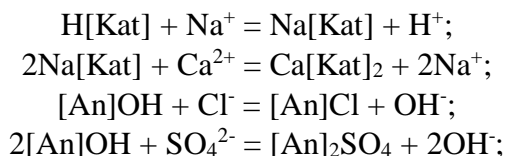
*The theoretical theses*

The essence of ion exchange is the solid (liquid) substance (resin) absorbs anions or cations from electrolyte solution, changing it on equivalent quantity of other ions with the same charge signal. There is the classification on anion exchangers and ampholytes. The exchanged ions are classified on cation and anion exchangers.

There are artificial high molecular organic ion exchangers. Poly electrolytes are almost undissolved in water and other solvents. The possibility of ion exchanging is caused by availability of active ion groups with moveable ions (counter ions) in ion exchangers. They can be exchanged on ions of another environment. If this active groups have acidity character (ankers or fixed ions –  $\text{SO}_3^-$ ,  $-\text{COO}^-$ ,  $-\text{PO}_3^-$  etc.), ion exchangers (cation exchangers) are capable to change moveable hydrogen or sodium ions on other cations from electrolyte solution. If the functional groups have alkalinity properties (anker ions  $-\text{NH}_3^+$ ,  $=\text{NH}_2^{3+}$ ,  $\equiv\text{S}^+$  etc.), ion exchangers change moveable hydroxide ions on other anions.

The certain polymer determines the space structure of ion exchanger. Cells consist of the matrix. These are high molecular, ion exchange materials and moveable ions, which are almost insoluble in water and other solvents. The last one's cause the charge of certain signal.

The ion exchange process can be described by reversible equilibrium heterogeneous chemical reactions of double exchange:



where [An] – anion exchanger; [Kat] – cation exchanger.

The most important characteristic of ion exchange sorbents is full exchange capacity. This is the theoretic number of ionic groups, containing in the single mass or volume of the ion exchanger.

The capacity is quantity of sorbed ion by the single mass or volume of the ion exchanger in equilibrium conditions (mmole/g, mmole/L). It can be determined in static and in dynamic conditions. The static exchange capacity is determined by contacting the mass of ion exchange material with certain volume of the investigated solution, until the equilibrium. The dynamic exchange capacity is the quantity of ions, absorbed by the same mass of ion exchange at continuous flowing of the electrolyte solution through the layer of ion exchange resin, until the penetration of ions. The full dynamic exchange capacity is determined by flowing of solution through the column of knowing quantity of the ion exchanger, until the composition of filtrate and inlet solution become the same.

The ion exchange reactions are reversible. That's why, if the concentration of ions  $\text{H}^+$ ,  $\text{Na}^+$ ,  $\text{OH}^-$  is increased extremely, the equilibrium moves to the left. This property is used at the regeneration of ion exchangers.

### *The methodic of work*

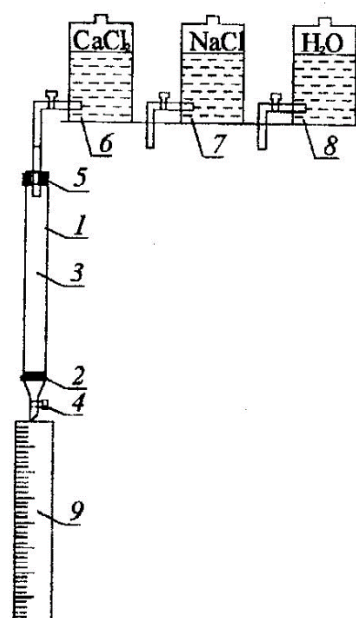
*Equipment:* volumetric flasks (100 cm<sup>3</sup>); volumetric cylinders (250 cm<sup>3</sup>) – 2 ones; pipettes (100 cm<sup>3</sup>); glass columns; bulbs for the titration (volume 250 cm<sup>3</sup>).

*Reactants:* cation exchanger CU-2; working solutions of  $\text{CaCl}_2$  and  $\text{NaCl}$ , ammonia buffer solution; the indicator – chrome dark blue; 0,01 M solution of Trilon B; argentum nitrate solution.

The installation of the dynamic exchange capacity of cation exchanger determination (pic. 4) consists of ion exchanger column-filter 1, presented by glass tube (diameter 15 – 25 mm); the bottom part of it includes glass diaphragm 2 for supporting of ion exchange resin layer 3. The cation exchanger quantity in column is 30 g. The glass taps and Mor's clamp on resin tube is designed for the regulation of liquid rate in the bottom part of column. From above the column is closed hermetically by resin tube with hole 5. For entering the investigated solution of  $\text{CaCl}_2$ ,  $\text{NaCl}$  solution to the column for regeneration of ion exchanger and water for washing up, the glasses 6 – 8 are set up. The reactants are entered for score of hydrostatic pressure from it., The volumetric cylinder 9 is used, for the determination of solution quantity, moving through column.

### **Experiment 1. Ion exchange filtration of calcium chloride solution**

The filtration rate of solution through the cation exchange filter is regulated at the beginning. Distilled water is passed through the filter from above to bottom. The regulation of flow rate is carried by regulated device 4. The time is determined by passing 20 – 25 cm<sup>3</sup> of water, accumulated in volumetric cylinder 9. When liquid flow achieves necessary rate, the tap is closed. The linear rate of filtration should be approx. 5 m/h.



Pic.4 The installation for the determination of dynamic exchange capacity of cation exchanger: 1 – column-filter; 2 – glass diaphragm; 3 – ion exchange resin; 4 – clamp or tap; 5 – stopper with hole; 6 – 8 – glasses with solutions and water; 9 – volumetric cylinder

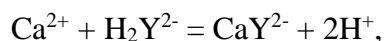
When the speed of liquid pouring has been determined, the solution of calcium chloride with molar concentration of equivalents 3,5 mmole/L is filtrated. The column with ion exchanger, instead of glass with distilled water 8, the glass 6 with  $\text{CaCl}_2$  is connected. Then the tap is opened and filtrate is picked up by portions (100 – 110  $\text{cm}^3$ ). The concentration of calcium cations is determined in it by complexonometric method. The filtration is stopped when the concentration of calcium ions in filtrate achieves above 0,05 mmole/L. After this the summary volume of filtrate has been passed through the ion exchange layer can be determined.

### **Experiment 2. The regeneration and washing up of the cation exchanger**

The glass 7 with solution of sodium chloride (mass fraction – 8 %) is connected to the column. It is passed through the layer of ion exchanger. The volume of  $\text{NaCl}$  solution should include the summary volume of  $\text{CaCl}_2$  solution, passed through the column with the same rate. Then excess of salt solution is washed up by connecting glass 8 with distilled water to the column. It is washed up, while water for washing would not contain chloride ions (sample with argenium nitrate). It's necessary to use not less than 1000  $\text{cm}^3$  of distilled water.

#### *The control methods*

The determination of content of calcium ions in filtrate is based on the reversible reaction



where  $\text{H}_2\text{Y}^{2-}$  - anion of Trilon B.

The reaction charged in alkaline buffer mixture (at pH 10), neutralized hydrogen ions, for moving the equilibrium to the formation of complex  $\text{CaY}^{2-}$ .

100  $\text{cm}^3$  of the filtrate is picked up (105 – 110  $\text{cm}^3$ ). Then 5  $\text{cm}^3$  of ammonia buffer solution and 2 – 3 drops of indicator are added into conical bulb with capacity 250  $\text{cm}^3$  by pipette or volumetric flask. The liquid is mixed and titrated by Trilon B solution from crimson to violet blue color.

The content of calcium ions is calculated by the formula:

$$C_{Ca^{2+}} = \frac{V_1 C_{H_2Y^{2-}} \cdot 1000}{V},$$

where  $C_{Ca^{2+}}$  - the concentration of calcium ions in filtrate, mmole/L;  $V_1$  – volume of Trilon B solution spent for the titration,  $cm^3$ ,  $C_{H_2Y^{2-}}$  - the concentration of Trilon B solution, mole/L;  $V$  – volume of water sample,  $cm^3$ .

The experimental data is recorded to the table 5.

**Table 5. The experimental data**

Number of sample	Volume of sample, $cm^3$	The volume of electrolyte passed through the filter, $cm^3$	The concentration of calcium ions in filtrate, mmole/L

It's necessary to build filtration curve in coordinates “electrolyte volume passed through the filter – calcium ions concentration in filtrate” and to determine the filtrate volume until the penetration of calcium ions by it. The penetration concentration of calcium ions equals 0,05 mole/L.

The dynamic exchange capacity is calculated by the formula

$$DEC = \frac{V_{pen} C_{Ca^{2+}}}{1000m},$$

where DEC – the dynamic exchange capacity of cation exchanger, mmole/g;  $V_{pen}$  – the volume of filtrate until the penetration of calcium ions,  $cm^3$ ;  $C_{Ca^{2+}}$  - the concentration of calcium ions in filtrate, mmole/L;  $m$  – mass of cation exchanger, g.

#### *The control questions*

1. Explain the essence of ion exchange. Write down equations of reactions.
2. Describe the structure and properties of artificial ion exchangers (moveable ions, exchange capacity, swelling, acidity-alkalinity properties, osmotic stability etc.).
3. How the dynamic exchange capacity of ion exchangers can be determined?
4. What the essence of the regeneration of ion exchangers?
5. Call the spheres of using ion exchange in water treatment processes. What is its preferences and drawbacks comparing with other methods?
6. Present the principal scheme of softening and desalination of water by ion exchange method. What requirements are to water quality in different branches of industry?

Literature: [1-8]; [17]; [22].

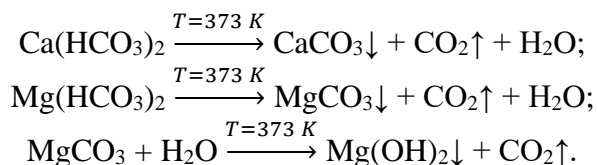
### **3.6 Laboratory work 6. Softening of natural water**

*The aim of work* is to conduct softening of natural water by soda-lime method. To compare it with the methodic of the determination of water hardness.

#### *The theoretical theses*

The water softening is the process, decreasing its hardness. The hardness of water is caused by salts of calcium and magnesium. Several kinds of water hardness are distinguished, i.e. carbonate and non-carbonate, and general or total hardness.

The carbonate hardness is caused by availability in water of hydro carbonates of calcium and magnesium. This kind of hardness is called temporary, because of it can be fully removed by boiling. Herewith hydro carbonates are decomposed, forming carbon (IV) oxide and precipitates of carbonates:



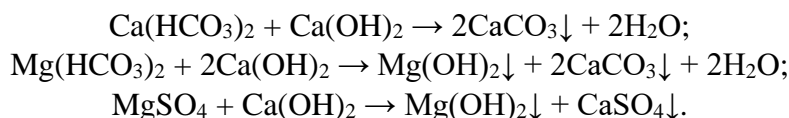
Non-carbonate (permanent) hardness is caused by availability in water of calcium and magnesium compounds (first of all – salts of strong acids). The hardness is expressed by mmole concentration of calcium and magnesium equivalents (mmole/L).

Water is classified by the value of hardness on very soft (until 1,5 mmole/L), soft (1,5 – 3,0 mmole/L), water of medium softening (3,0 – 4,5 mmole/L), enough hard (4,5 – 6,0 mmole/L), hard (6,0 – 11,0 mmole/L) and very hard (above 11,0 mmole/L). Water is considered suitable with hardness not more 7 mmole/L) for requirements of commercial-drinking water supply at THE STATE SANITARY NORMS AND RULES 2.2.4-171-10. Salts, caused water hardness, don't harmful for human, but large quantity of it in water makes it unsuitable for commercial-household needs.

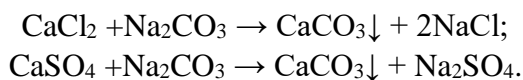
Water, containing calcium and magnesium salts, is impossible for using for obtaining vapor. Such water causes the formation of dense layer of scale, causing overheating of boiler and its rapid destroying. The water hardness, using in vapor generators, shouldn't be above 0,0002 mmole/L. Water with increased carbonate hardness can't be used in cooling systems.

The thermal, reagent, ion exchange and combine methods are usually used for water softening. The thermal methods are based on heating of water, its distillation and freezing.

The reagent methods allow to transform calcium and magnesium compounds, soluble in water, to almost insoluble. Lime, calcined soda, sodium or barium hydroxides, oxalate acid, sodium phosphates etc. are used as reagents for water softening. The lime-soda method is used the most widely among reagent methods. Its essence is in processes, describing by following equations:



Soda removes non-carbonate calcium water hardness:

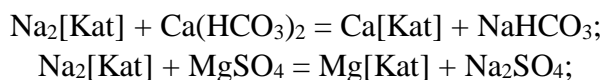


The water hardness can't be fully removed by reagent methods because of such compounds, as  $\text{CaCO}_3$  and  $\text{Mg}(\text{OH})_2$  has very low solubility in water. That's why, the lime-soda method is used, if it's necessary to soft natural water to relatively shallow residual hardness (approx. 1 mmole/L). The phosphate method gives deeper softening (almost until fully desalination) among reagent methods, and also the method of ion exchange.

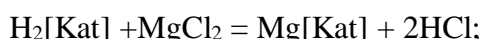
The essence of ion exchange method is following. The solid substance (ion exchanger) can exchange ions on equivalent quantity of ions with the same sign of charge. The ion exchanger is often presented in apparatus in non-moving state, and water is passed through the layer of ion exchanger. Ion exchangers are substances in solid (sometimes – liquid) state. They are insoluble in

water of the natural or artificial origin. Ion exchangers include natural minerals (zeolites, glauconitic etc.), artificial substances (permutes) and also synthetic resins, sulfated coal etc. The artificial ion exchangers are the most often used in water preparation processes. Cation and anion exchangers are distinguished, depending on the sign of charge. Ion exchange is reversible process. This property is one more advantage of the process, because it gives possibility to regenerate ion exchanger.

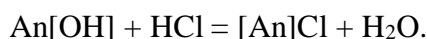
If ion exchanger has moveable cation group like  $\text{Na}^+$  (then it will call cation exchanger), the ion exchange process flow by the schemes:



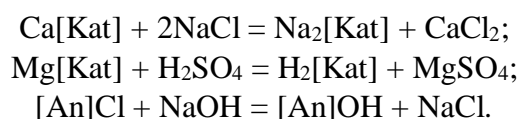
if cation exchanger is in H-form:



if ion exchange flow among anions, the process will be following:



The regeneration of exhausted ion exchangers is conducted by solutions of sodium chloride, sulfuric or chloride acid, alkaline. Herewith the following processes are occurred:



Ion exchange is used not only for softening natural, but also for purification of waste (the most often – industrial) waters, allowing to utilize valuable, harmful and toxic water impurities. Herewith waste waters can be purified until the edge allowable concentration (EAC). Then they can be used in technology processes or in systems of reversible water supply. Ion exchange method is widely used for purification of waste waters of metallurgical, chemical, coke-chemical, machine-building enterprises and other branches of industry.

### *The methodic of conducting work*

*Equipment:* pipettes; volumetric cylinder ( $250\text{ cm}^3$ ); conical bulbs for the titration ( $250\text{ cm}^3$ ); heat-resistant bulbs for boiling; funnels; paper filters.

*Reactants:* 0,1 M solution of chloride acid; 0,04 mmole/L solution of sodium hydroxide; 0,1 mmole/L solution of calcined soda; 0,05 M solution of Trilon B (disodium salt of ethylenediaminetetraacetate acid); ammonia buffer solution (pH 10); indicators – methylene orange, phenolphthalein, chromic dark-blue.

All kinds of hardness are determined in water sample, proposed by teacher, firstly analytically. Then the quantity of reagents is calculated. The softening process is conducted. Then the residual hardness of water sample is determined and the softening degree is calculated.

### **Experiment 1. The determination of carbonate hardness of water**

It's enough to determine the content of  $\text{HCO}_3^-$  ions and to form neutral salts by water titration by chloride acid. At the same time, except  $\text{HCO}_3^-$  ions, water can contain  $\text{OH}^-$  and  $\text{CO}_3^{2-}$  ions. They also form neutral salts at the titration by chloride acid.  $\text{HCO}_3^-$ ,  $\text{OH}^-$  and  $\text{CO}_3^{2-}$  ions cause total water

alkalinity, determining by chloride acid, spent for titration of water until pH 3,6 with methylene orange.  $\text{OH}^-$  and  $\text{CO}_3^{2-}$  ions content is determined by the quantity of chloride acid, spent for titration until pH 8,6 with phenolphthalein. If the alkalinity by phenolphthalein is zero, the total alkalinity is equal carbonate hardness,  $A_{tot} = H_c$ .

If the alkalinity by phenolphthalein is above zero:

$$H_c = A_{tot} - A_{ph},$$

where  $A_{ph}$  – the alkalinity by phenolphthalein.

100 cm<sup>3</sup> of certain water sample is picked up by pipette or volumetric flask. Then it is transited to conical bulb (250 cm<sup>3</sup>). 2 - 3 drops of phenolphthalein are added. If water obtains pale pink color, it is titrated by 0,1 M solution of chloride acid until transparency. Then 2 - 3 drops of phenolphthalein are added into this bulb and titration is continued by chloride acid from tallow to rose color.

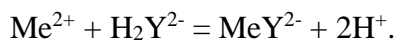
The carbonate hardness of water is determined by the formula

$$H_c = \frac{(V_{tot} - V_{ph})}{V} C_{HCl} \cdot 1000,$$

where  $H_c$  – the carbonate hardness of water, mmole/L;  $C_{HCl}$  – the concentration of chloride acid, mole/L;  $V_{tot}$  – total volume of chloride acid solution spent for the titration, cm<sup>3</sup>;  $V_{ph}$  – volume of chloride acid spent for the titration only with phenolphthalein, cm<sup>3</sup>;  $V$  – volume of water sample, taken for analysis, cm<sup>3</sup>.

### ***Experiment 2. The determination of non-carbonate and total water hardness***

The total water hardness is determined by complex metric method. Herewith, calcium and magnesium ions form complex compounds with Trilon B:



100 cm<sup>3</sup> of analyzed solution is picked up by pipette or volumetric flask, transited to conical bulb for titration (volume 250 cm<sup>3</sup>). The 5 cm<sup>3</sup> of ammonia buffer solution and 3 -5 drops of indicator chromic dark blue are added. Herewith, if water contains  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions, the solution obtains violet-crimson color. The solution is slowly titrated by 0,05 M solution of Trilon B until grey-blue color.

The total water hardness is calculated by the formula

$$H_{tot} = \frac{V_1 C_1 \cdot 1000}{V},$$

where  $H_{tot}$  – the total water hardness, mmole/L;  $V_1$  – volume of Trilon B solution spent for the titration, cm<sup>3</sup>;  $C_1$  – the concentration of trilon B solution, mole/L;  $V$  – volume of water sample, taken for analysis, cm<sup>3</sup>.

The non-carbonate hardness of water is determined as difference between total and carbonate hardness:

$$H_{nc} = H_{tot} - H_c.$$

### ***The calculation of reagents quantity for softening of water***

If water hasn't magnesium hardness, the volume of lime milk is calculated, considering carbonate water hardness:

$$V_{Ca(OH)_2} = \frac{H_c V_{H_2O}}{1000 C_2},$$

where  $V_{Ca(OH)_2}$  – volume of lime milk,  $\text{cm}^3$ ;  $H_c$  – the carbonate hardness of investigated water,  $\text{mmole}/\text{cm}^3$ ;  $V_{H_2O}$  – water volume necessary for softening,  $\text{cm}^3$ ;  $C_2$  – the concentration of  $\text{Ca(OH)}_2$  in lime milk,  $\text{mole}/\text{L}$ .

The quantity of soda solution for water softening is calculated, considering non-carbonate hardness:

$$V_{Na_2CO_3} = \frac{H_{nc} V_{H_2O}}{1000 C_3},$$

where  $V_{Na_2CO_3}$  – volume of soda solution,  $\text{cm}^3$ ;  $H_{nc}$  – the non-carbonate hardness of investigated water,  $\text{mmole}/\text{cm}^3$ ;  $C_3$  – the concentration of soda solution,  $\text{mole}/\text{L}$ .

### ***Experiment 3. The softening of water and determination of residual hardness***

Some volume of the sample is transferred into the bulb ( $500 \text{ cm}^3$ ) by volumetric cylinder (should be produced from heat-resistant glass). Then quantities of lime milk and soda solutions are added. The solution is boiled 10 – 15 min. (from the beginning of boiling). Then bulb is cooled to room temperature. Water is filtrated through the paper filter.  $100 \text{ cm}^3$  of it is picked up by pipette to the titration flask, and residual hardness of water is determined after softening. The analysis and calculations are conducted the same.

The degree of water softening is calculated by the formula

$$x = \frac{H_{tot} - H_{res}}{H_{tot}},$$

where  $x$  – the degree of softening, share units;  $H_{tot}$  – the total hardness of water until softening,  $\text{mmole}/\text{L}$ ;  $H_{res}$  – the residual hardness of water after softening,  $\text{mmole}/\text{L}$ .

### *The control questions*

1. The availability of what substances causes the hardness and alkalinity of water?
2. How the kinds of water hardness can be classified on?
3. What methods of water softening are used in industry?
4. What the essence of reagent and ion exchange methods of water softening?

Literature:[1-12];[17-22].

## ADDITIONS

### *Addition 1*

#### ORIGIN AND APPOINTMENT OF WATER

Version	Water, passing purification	The appointment of purified water
1	Natural water (surface)	Drinking water
2	Natural water (underground)	Drinking water
3	Natural water (surface origin)	Technic water for vapor
4	Industrial waste waters	Recycle
5	Household waste waters	Slope to pound
6	Mixture of industrial and household waste waters	Slope to biological pounds
7	Industrial waste waters	Recycle
8	Natural water (surface)	Technic water for vapor
9	Industrial waste waters	Recycle
10	Industrial waste waters	Technic water
11	Industrial waste waters	Slope to pound
12	Mixture of industrial and household waste waters	Slope to city canalization
13	Industrial waste waters	Recycle
14	Natural water (surface origin)	Technic water for vapor
15	Household waste waters	Slope to pound
16	Industrial waste waters	Recycle
17	Industrial waste waters	Slope to plant canalization
18	Natural water (surface)	Technic water for cooling systems
19	Mixture of industrial and household waste waters	For recycle by enterprise
20	Industrial waste waters	Recycle
21	Household waste waters	Slope to pound
22	Natural water (underground origin)	Technic water for cooling systems
23	Industrial waste waters	Slope to plant canalization
24	Household waste waters	Slope to pound
25	Industrial waste waters	Recycle

TASKS FOR CHOOSING AND CALCULATING OF APPARATUS OF WATER  
PREPARATION SCHEME

Version	Main apparatus (for calculating) in water preparation scheme	Calculating parameters
1	Horizontal decanter	Area of precipitation surface, decanters quantity
2	Sand filter	Quantity and filtration area
3	Na-cation exchanger filter	Area of filtration surface, filters quantity
4	Radial decanter	Area of precipitation surface
5	Aero-tank-propellant	Aero-tank volume, aeration time
6	Oil traps	Length, sectional area
7	Extractor (one degree)	Extractant volume
8	Sand traps	Water glass surface, length
9	Rapid mechanic filter	Area of filtration surface, filters quantity
10	Soluble tank	Cooling tower surface
11	Aero-tank-decanter	Volume, area of decantation surface
12	Primary horizontal decanter	Overall dimensions – length, width, depth
13	Vertical decanter	Area of precipitation surface
14	H-cation exchanger filter	Area of filtration surface, filters quantity
15	Aero-tank-decanter	Aeration time, aeration zone volume
16	Floater	Overall volume
17	Coagulator with suspended precipitate layer	Area of coagulation surface
18	Partition camera of formation of flakes	Volume, area
19	Bio-filter	Area of filtration surface
20	Extractor (two degrees)	Extractant volume
21	Aero-tank-propellant with regenerator	Aero-tank volume, degree of active silt recycling
22	OH-anion exchange filter	Area of filtration surface, filters quantity
23	Grille-crusher	Quantity of notches and grilles
24	Aero-tank-mixer with regenerator	Aero-tank volume, degree of active silt recycling
25	Adsorber with fixed layer of sorbent	Dose of sorbent

Literature:[1-22].

## CHARACTERISTICS AND INDICATORS OF QUALITY OF TREATING WATER

Version	Power of station, m <sup>3</sup> /h	pH	Suspended substances, mg/L		Color, degrees	Smell, mark	COD, mg of oxygen in 1 L	BOD, mg of oxygen in 1 L	Dissolved Gases, mg/L	Pollutants, mg/L	Total salt content, mg/L	Coli-index
			hard dispersion	colloidal								
1	1600	6,5	120	80	50	4	7	5	8 (CH <sub>4</sub> )	-	800	140
2	1200	8,0	2	-	20	2	12	-	10 (H <sub>2</sub> S)	10 (Fe total)	3600	270
3	600	7,0	1500	600	80	4	15	-	-	2,0 (Mn)	1200	1000
4	300	2,0	260	300	150	-	150	-	-	120 (Cr)	4000	-
5	2000	6,5	250	180	360	4	200	180	-	70 (SAS)	1800	10000
6	800	7,2	150	70	500	5	400	250	-	250 (oil-products)	1500	-
7	400	4,5	80	50	22	5	200	130	-	6500 (phenols)	800	-
8	2200	6,5-7,5	120	40	35	4	80	45	12 (CH <sub>4</sub> )	40 (organic comp.)	2100	4000
9	500	7,0	150	40	6	3	122	80	-	85 (Ni, Co)	4700	-
10	180	2,5	75	30	130	5	60	-	-	8 (Fe <sup>2+</sup> )	6000	10
11	1100	3,7	145	70	35	5	250	180	-	320 (heavy met. salts)	12700	-
12	1600	8,5	60	35	15	4	280	120	-	150 (albumen subs.)	8300	3000
13	150	4,2	40	28	58	3	160	75	24 (NH <sub>3</sub> )	85 (nitrates)	4200	-
14	125	7,5	310	45	43	3	100	60	-	50 (plankton)	3800	-
15	85	9,0	200	80	27	5	510	450	-	65 (synt. wash means)	2300	1200
16	80	4,0	120	100	380	5	200	120	-	500 (oil-products)	1800	-
17	60	2,0	180	65	33	3	30	20	-	12 (mercury comp.)	5000	-
18	140	6,5	190	70	12	2	44	25	-	-	2200	1000
19	200	8,0	95	50	15	4	680	550	-	-	3700	10000
20	1100	5,0	65	40	17	5	300	80	-	4900 (aniline)	700	-
21	800	11,0	400	85	5	3	440	370	-	180 (fats)	1300	1000
22	420	8,0	5	-	-	3	32	15	-	12 (fluoride comp.)	11300	8
23	130	5,5	27	15	45	5	180	85	-	50 (org. solvents)	2900	-
24	170	6,5	500	150	30	5	280	220	-	140 (SAS)	1450	10000
25	700	6,0	70	30	40	5	140	90	-	1100 (phenol)	600	-

## INDICATORS OF WATER QUALITY AFTER TREATMENT

Version	pH	Suspended substances, mg/L		Color, degrees	Smell, mark	OCC, mg of oxygen in 1 L	OBC, mg of oxygen in 1 L	Dissolved Gases, mg/L	Pollutants, mg/L	Total salt content, mg/L	Coli-index
		hard dispersion	colloidal								
1	6,5 – 7,0	-	5	2	1	-	-	-	-	500	3
2	6,5 – 8,0	-	-	1	1	2	-	-	0,300	800	3
3	7,5 – 8,0	-	-	-	-	-	-	-	0,050	10	-
4	6,5 – 8,5	10	5	5	-	10	-	-	2,000	200	-
5	6,5 – 8,5	30	15	12	4	30	25	-	2,000	500	100
6	6,5 – 8,5	40	20	10	3	40	25	-	25,000	500	-
7	6,0	15	10	8	5	40	20	-	100,000	400	-
8	6,5 – 7,5	-	2	-	-	5	-	-	-	0,25	-
9	6,0 – 8,0	12	10	3	3	25	15	-	2,500	220	-
10	6,5 – 7,0	-	-	2	1	3	-	-	0,300	1000	3
11	6,5 – 8,5	40	30	8	5	20	15	-	until EAC	1600	-
12	6,5 – 8,5	20	15	6	4	30	25	-	20,000	2000	150
13	6,5 – 8,5	15	15	5	2	30	15	2	10,000	1000	-
14	7,5	-	-	2	-	-	-	-	-	0,5	-
15	6,5 – 8,5	20	10	2	3	40	15	-	2,000	1000	100
16	6,5 – 8,5	30	15	12	5	40	25	-	25,000	1000	-
17	6,5 – 8,5	20	10	4	3	25	10	-	0,005	1000	-
18	6,5 – 8,5	5	5	3	2	12	5	-	-	50	10
19	6,5 – 8,5	15	5	3	2	30	15	-	-	100	30
20	6,5 – 8,5	10	5	3	2	20	15	-	15,000	25	-
21	6,5 – 8,5	40	20	5	3	30	15	-	5,000	1300	100
22	6,5 – 8,5	-	-	2	3	30	15	-	0,750	1200	3
23	6,5 – 8,5	10	5	5	5	10	5	-	until EAC	150	-
24	6,5 – 8,5	10	5	5	2	38	15	-	1,500	150	100
25	6,5 – 8,5	20	10	15	5	25	15	-	20,000	80	-

**WATER IMPURITIES CLASSIFICATION BY ITS PHASE AND DISPERSION CHARACTERISTICS AND METHODS RECOMMENDED FOR WATER TREATMENT**

Processes	Technological methods of water treatment	Sphere of using	Reactants (and its consumption per 1000 m <sup>3</sup> of water in kg)	Equipment of stations of water preparation	Removal degree of impurities from water
1	2	3	4	5	6
<b>Methods for removing impurities of the first group (particle size is above 10<sup>-5</sup> cm)</b>					
1. Mechanic non-reagent separation	Creaming	Hard-dispersive impurities (above 500 mg/L), color until 50 deg.	-	Decanters	50...70 %
	Filtration	Suspended substances (until 50 mg/L), color until 50 deg.	-	Slow filters	95...99 % of microorganisms until drinking water norm
	Filtration	Suspended substances (until 1000 mg/L), color until 50 deg.	-	Previous filters	60...80 %
	Microfiltration	Plankton (above 1000 cells per 1 L), suspended substances	-	Micro filters	70...95 %
	Centrifugation	Hard- and small-dispersive impurities	-	Centrifuges, hydro-cyclones	80...90 %
2. Adhesion on high-dispersive and grain materials	Filtration of coagulated suspension through the layer of grain backfilling	Coagulated suspension (10...15 mg/L)	Flocculants: PAA [0,01...0,04], AC [0,2...1,0]	Rapid filters, two- or multilayer filters	Until norms of drinking water
	Filtration by contact coagulation	Suspended substances (until 150 mg/L), color until 150 deg.	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> or FeCl <sub>3</sub> [10...120], PAA [0,2...0,6], AC [0,1...2,0]	Coagulators, contact filters	

*Continuing of add. 5*

1	2	3	4	5	6
3. Adhesion by alumina or iron hydroxides or clay materials	Water treatment by coagulants	Suspended substances and color without limits, pathogen bacteria, spores	$\text{Al}_2(\text{SO}_4)_3$ [40...250], $\text{FeCl}_3$ or $\text{FeSO}_4$ [20...150], lime, soda	Equipment for preparation and dosage of reactants, mixers, cameras of forming flakes, decanters, filters	Until norms of drinking water
	Treatment by clay materials	Pathogen bacteria, spores etc.	Clay materials (palygorskyte, montmorillonite) [100...500]		98...99,9 %
4. Adhesion by flocculants	Water treatment by coagulants and flocculants with creaming and filtration	Suspended substances and color are no-limited, pathogen bacteria	$\text{Al}_2(\text{SO}_4)_3$ [40...250], $\text{FeCl}_3$ or $\text{FeSO}_4$ [20...150], PAA [0,01...3 % from quantity of suspended substances] AC [20 % from dose of waterless coagulant]	The same	Until norms of drinking water
5. Flotation	Non-reagent flotation	Oil, butters, non-filterable mass (until 2000 mg/L)	Air	Floater and devices for air desperation	0,9
	Reagent flotation		Air, fatty alcohols [10], $\text{Al}_2(\text{SO}_4)_3$ or $\text{FeCl}_3$ [25...50], AC [10]	Floater and devices for air desperation and reagents dosage	90...99 %
6. Bactericide influence on pathogen microorganisms	Water treatment by oxidants: chlorination	Pollution of bacteria	Chlorine [1...20] or chlorine (IV) oxide [1...5]	Chlorine storages, chlorinators, mixers	Standard by coli-index
	Ozonation		Ozone [0,5...50]	Ozonation devices, contact tanks	
	Ionization		Metallic silver	Ionization devices	
	Water treatment by radiation: ultrasonic	Pathogen bacteria	Electric energy	Ultrasonic installations	0,95
	UV-rays		Electric energy	Bactericide installations	98...99,9 %

Continuing of add. 5

1	2	3	4	5	6
<b>Methods for removing impurities of the second group (particle size <math>10^{-5} \dots 10^{-6}</math> cm)</b>					
1. Oxidation	Chlorination	Increased content of colloidal suspended substances and HMC caused color (35...250 deg.) and water oxidation	Chlorine [1...20] or chlorine (IV) oxide [1...5]	Chlorine storages, equipment for obtaining of chlorine (IV) oxide, chlorine, chlorinators, mixers, contact tanks	Water of standard quality
	Ozonation		Ozone [0,5...20]	Ozone devices and devices for inputting ozone into water	
2. Adsorption by alumina and iron hydroxides or high-dispersive clay materials	Coagulation in free volume with following decantation and filtration	The same	$\text{Al}_2(\text{SO}_4)_3$ [40...200], $\text{FeCl}_3$ [30...200], lime, soda, NaOH	Equipment for preparation and dosing of reagents, cameras for flakes forming, decanters, coagulators; filters	Water of standard quality
	Water treatment by high-dispersive muddies and coagulants	Low muddy, water pollution by viruses	$\text{Al}_2(\text{SO}_4)_3$ [40...200], $\text{FeCl}_3$ [30...200], lime, soda, NaOH, adding bentonites or palygorskyte [50...200] etc.		
	Contact coagulation	Colloidal particles and high-molecular substances (35...150 deg.) in conditions of low concentrations of suspended substances	$\text{Al}_2(\text{SO}_4)_3$ [10...120], PAA [0,2...0,6], AC [0,1...2,0]	Equipment for preparation of solutions mixers, cameras for flakes forming	
3. Adhesion by flocculants	Water treatment by flocculants		High-molecular poly electrolytes [2...15]	The same	Water of standard quality

Continuing of add. 5

1	2	3	4	5	6
4. Removing of viruses	Water treatment by oxidants: chlorination	Water pollution by viruses	Chlorine [5...20], chlorine (IV) oxide [1...10]	Chlorine storages, chlorinators, mixers	Water of standard quality
	ozonation		Ozone [0,5...20]	Ozone and contact tanks	
	ionization (ions of silver and other metals)		Metallic silver [0,05...0,5]	Ionization devices	
Methods for removing impurities of the third group (particle size 10 <sup>-6</sup> ...10 <sup>-7</sup> cm)					
1. Desorption of gases and volatile organic compounds	Aeration	Gases and volatile organic compounds offer unpleasant flavors and smells to water	Air	Sprinkle basins, cooling tanks, gas removing devices	From CO <sub>2</sub> – 65...80 %, H <sub>2</sub> S - until 0,3...0,5 mg/L
2. Oxidation	Chlorination	Non-volatile organic compounds, H <sub>2</sub> S (0,3...0,5 mg/L)	Chlorine [1,5...10] or chlorine dioxide [0,5...1,2]	Chlorinators, mixers, devices for chlorine dioxide getting	H <sub>2</sub> S, other – depending on compound
	Ozonation	If chlorination efficiency isn't enough	Ozone [2...4]	Ozone devices, contact tanks	Depending on compounds
	Treatment by potassium permanganate	If pollutions are little	KMnO <sub>4</sub> [3...10]	Devices for preparation and dosage of KMnO <sub>4</sub>	Depending on compounds
3. Adsorption on activated carbon and other materials	Coal treatment	Unpleasant flavors and smells of natural origin and also in waste waters	Coal of different marks [5...20]	Devices for mixing water with coal suspension	80...95 %
	Water purification on coal filters and adsorbers with suspended layer of coal	Aromatic compounds (until 2000 mg/L)	Granulated coal	Adsorbers, furnaces for coal activation and regeneration	80...95 %
4. Extraction by organic solvents	Phenol removing phenol from water	Phenols (above 2000 mg/L)	Butyl acetate, ethyl acetate, benzene etc.	Extraction devices	80...90 %
5. Evaporation	Vapor-circulation method	Volatile organic substances, phenols	Vapor at t = 100...105 °C	Columns for removing by volatilization	90...95 %
	Azeotrope stripping	Formation of azeotrope mixture		Columns for removing by volatilization	90...95 %

*Continuing of add. 5*

1	2	3	4	5	6
6.Biochemical decomposition	Aerobic method	Waste waters pollution	Active silt, bio layer, air	Aero-tanks, bio-filters, decanters	90...98 %
	Anaerobic method	Concentrated waste waters, precipitates	Anaerobic microorganisms	Methane-tanks	90...98 %
7.Thermal oxidation methods	Flame calcination in gas phase	The same	Air	Cyclone furnaces	90...95 %
	Liquid-phase oxidation		Air	Devices for liquid phase oxidation	90...95 %
Methods for removing impurities of the fourth group (particle size – until 10 <sup>-7</sup> cm)					
1.Hyperfiltration	Ions removing by reverse osmosis	TSC 20...30 g/L	Electric energy [5...10 kW·h per 1 m <sup>3</sup> of water]	Devices with half-injection membranes	95...98 %
2.Transferring of ions into low-dissociated substances	Neutralization (by adding acid or alkaline)	pH 6,5...9	CaO, Na <sub>2</sub> CO <sub>3</sub> , NaOH, H <sub>2</sub> SO <sub>4</sub> , HCl, CO <sub>2</sub>	Devices for preparation and dosage of solutions, mixers	Until necessary parameters
	Complex ions forming (stabilization)	Index of water saturation I>0	Sodium hex metaphosphate, sodium three poly phosphate [2...20]		Prevention of forming corrosion
3.Softening (forming of low-soluble compounds of calcium and magnesium)	Thermal method	Carbonate hardness, calcium sulfate, muddy less than 50 mg/L	Heating	Thermal softer of water	Carbonate hardness – until 0,018 mmole/L
	Lime-soda method	Total hardness 2,5...15 mmole/L, muddy until 50 mg/L	Lime, soda	Mixers, rotor reactor, coagulators, decanters	Hardness – until 0,018 mmole/L
	Phosphate method	Total hardness until 1 mmole/L	Na <sub>3</sub> PO <sub>4</sub>		Hardness until 0,02...0,025 mmole/L
4.Forming of low-soluble metal hydroxides	Removing of color and heavy metals and also magnesium hardness	Ions of color and heavy metals, high magnesium hardness	Lime and NaOH	Devices for preparation and dosage of solutions, mixers, decanters, coagulators, filters	Until edges of metal hydroxides solubility

*Ending of add. 5*

1	2	3	4	5	6
5.Fixing of ions by solid phase of sorbents: H-, Na-cation exchanging	Softening (by using of unmovable layer of cation exchanger	Total hardness until 7 mmole/L, suspended substances 8...10 mg/L	Cation exchangers, sulfated coal, NaCl, H <sub>2</sub> SO <sub>4</sub> , HCl	Cation exchanger filters, devices for preparation of regeneration solutions, adsorbers	Hardness until 0,0025...0,025 mmole/L
	Color metals removing	Waste waters			Hardness until 0,0025...0,025 mmole/L
6.Fixing of ions by solid phase of sorbents: H-, OH-ion exchanging	Freshness	TSC 3...4 g/L, suspended substances – until 8 mg/L, color – until 30 deg.	Cation exchangers, anion exchangers, sulfated coal, NaOH, H <sub>2</sub> SO <sub>4</sub>	Ion exchange filters, devices for preparation of regeneration solutions	75...90 % (until TSC 500...1000 mg/L)
	Desalting				99,5...99,9 % (until TSC 1...15 mg/L)
7.Separation in different phase states of water	Transferring water into gas phase (distillation)	TSC 20...35 g/L	Vapor, fuel	Evaporators of different types	99,9 % (until salt content of distilled water 20...50 mg/L)
	Ions recombination in non-mixing liquids (extraction)	TSC 3...4 mg/L, calcium and magnesium salts absent	Secondary and third amines [2...4]	Extraction and rectification columns	95...99 %
	Transferring water into solid phase (freshness by freezing)	TSC until 35 g/L	Different cooling agents, natural cold	Devices by using artificial cold, areas for freezing	92...97 %
8.Using of ions moveable in electric field	Electric dialysis	TSC 3...10 g/L, muddy until 2 mg/L, iron content – until 0,3 mg/L	Electric energy expenses – 20 kW·h per 1 m <sup>3</sup> of water, ion exchange membranes	Devices by electrochemical water desalting	TSC until 500...1000 mg/L

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