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METHODICAL GUIDELINES

to the Laboratory works to the academic discipline «Chemistry» for students of higher education of the first (bachelor's) level of educational and professional program of the specialty ***G19 Construction and Civil Engineering*** all forms of education

МЕТОДИЧНІ ВКАЗІВКИ

до виконання лабораторних робіт з навчальної дисципліни «Хімія» для здобувачів вищої освіти першого (бакалаврського) рівня за освітньо-професійною програмою спеціальності **G19 «Будівництво та цивільна інженерія»** денної, заочної та дистанційної форм навчання (англомовне видання)

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Lab equipment

FOREWORD

Lab workshop, along with **Lectures** and **Seminars**, is an integral part of the ***Chemistry course***. This Lab workshop allows students to master the skills of conducting a chemical experiment by following the instructions (complying with Lab safety rules), observing the processes, making conclusions.

This issue contains a description of 4's Lab workshop lessons for students of specialty G19 Construction and Civil Engineering. Each Lab contains detailed instructions for every experimental work and tasks for individual preparation.

When preparing for each lesson, every student must study the theoretical material using recommended textbooks or other sources. We still recommend using primarily Chemistry course textbooks, where the material is systematic, in contrast with the scattered material of the web. Performing self-practice tasks for each lesson will allow you to successfully defend each Lab. Also, we advise you to write preparation notes of experiments in a **Lab workbook** *before the lesson*, leaving next the necessary space for recording reactions, observations, and conclusions. This will save class time, which can be used to defend the previous work. If the student did not defend the Lab during classroom time, this can be done during consultations according to the schedule.

RULES FOR LAB WORK

- Lab work is performed in teams, two students at a time (or another way by the choice of the teacher and students).
- Each student is assigned a permanent workplace in the laboratory for the entire period.
- It is necessary to keep a separate **Lab Workbook** to record the results of the experiments (a notebook of 18 pages or less is enough).
- The following data must be entered into the laboratory workbook for each experimental study: which reagents were used, the course of the experiment, your observations, for example, whether there is a change in the aggregate state of the reagents – precipitation, gas evolution, dissolution of the precipitate, color change, etc. If an indicator was added to the reagents, also describe the color change or its absence, and explain this.
- Be sure to write down the reaction equations and names of the products of the reaction. Formulate conclusions for each experiment (2-3 sentences).
- A laboratory lesson usually has several experiments. Please, make sure that all of them are correctly designed (reactions, observations, conclusions).
- After completing, the workbook must be given to the teacher for review and signature.

LAB SAFETY RULES

- Students and staff have to use overalls (gowns), safety glasses, and other protective equipment.
- Not allowed to eat and drink in the laboratory, apply cosmetics, etc.
- Not allowed to touch your face with your fingers at all; if necessary, do it with the back of your hand.
- Not allowed to violate discipline, disturb colleagues, make noise, or disobey the instructions of the teacher or laboratory assistant. Violators are removed from the laboratory immediately.
- Laboratory work can only be started with the permission of the teacher.
- Quantities of Reagents should be taken as specified in the instructions. Reagent beakers should be closed with corks and returned back in place. The excess reagent should not be poured back into the beaker.
- All experiments with concentrated acids, alkalies, and other harmful substances should be carried out only under a hood.
- Hot glass containers cannot be placed on the laboratory table.
- In all cases of accidents, contact the teacher!
- After experimenting, you must wash your hands thoroughly!

LAB 1. OXIDES, BASES, AMPHOTERIC HYDROXIDES

TASKS FOR SELF-PRACTICE

1. Determine the valence of the element that forms the oxide and name the oxides: SO_2, Cl_2O_5, Cl_2O, Al_2O_3, CrO_3, MnO_2, N_2O_5.

2. Write the formulas of the higher oxides of the following elements: Sulfur, Phosphorus, Manganese, Chlorine, Sodium, Aluminum, Nitrogen, and Silicon. Name these oxides.

3. Which of the listed pairs of oxides can interact with each other, forming salts: CaO and Al_2O_3; BaO and Cr_2O_3; BaO and Na_2O; K_2O and P_2O_5, SO_3 and MgO? Write the equations of the corresponding reactions.

4. Indicate the chemical nature of the oxides: CO, MgO, CrO, Cr_2O_3, MnO, MnO_2, MnO_7, N_2O. Which oxides can interact: a) with sodium hydroxide; b) with sulfuric acid? Write the equations of the corresponding reactions.

5. Write the equations of the reactions of obtaining:

a) aluminum hydroxide;

b) iron(II) hydroxide;

c) calcium hydroxide;

d) zinc hydroxide.

Which of the listed hydroxides have amphoteric properties? Write down the equations of the reactions characterizing the chemical nature of these hydroxides.

The student should know:

What are oxides (definition, examples, reactions), know their preparation, properties, types of oxides, salt-forming, non-salt-forming – basic, acidic, amphoteric, know examples, typical reactions **are required**!

EXPERIMENTAL PART

1. Chemical properties of basic oxides (soluble and insoluble in water)

Experiment 1.1

Take two test tubes, into one add a small amount of calcium oxide powder (1-2 spatula of powder), into second – same amount powdered copper (II) oxide. Add 1-2 mL of distilled water and 1-2 drops of indicator (phenolphthalein) to each test tube.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (gas evolution, dissolution, precipitation)?
- ✓ Is there a change in the color of the indicator? Explain the indicator color change.
- ✓ Write the reaction equation, and name all the substances formed.
- ✓ Conclude about which basic oxides interact with water, which do not, and what products are formed.

Experiment 1.2

Take two test tubes, into one add a small amount of calcium oxide powder (1-2 spatula of powder), into second – same amount powdered copper (II) oxide, add 1-2 mL of hydrochloric acid solution to each test tube. To speed up the reaction, heat test tube with a gas burner until the color changes (heating is made by the teacher) or wait 5-10 minutes.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation of substances (evolution of gas, dissolution, precipitation)?
- ✓ Write the reaction equations, and name all the substances that is formed.
- ✓ Make a conclusion of interaction of basic oxides with acids.

2. Chemical properties of acidic oxides

Experiment 2

Pour 5-6 ml of lime water (calcium hydroxide solution $Ca(OH)_2$) into the test tube, and add 1-2 drops of indicator phenolphthalein. Bubble gaseous carbon dioxide into the water until the color changes and a precipitate forms (**performes by the teacher**).

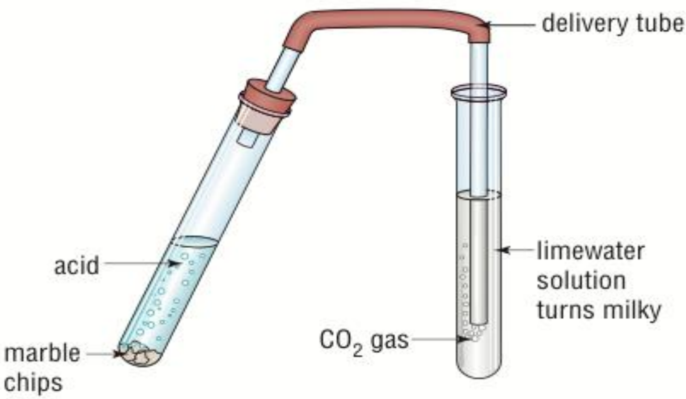

Fig.1. Obtaining gas Carbon dioxide (IV)

N.B. can be obtained in several ways, from a cylinder with compressed CO_2 gas or by the reaction of an acid (usually HCl) on pieces of limestone or marble (both are $CaCO_3$). This reaction is conveniently carried out in a *Kipp apparatus* or in a test tube and the cork with a gas delivery tube.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Is there a change in the color of the indicator? Explain the change.
- ✓ Make up the reaction equation, and name all the substances formed.
- ✓ In the conclusions, explain the reaction of acidic oxide with hydroxide. What products are formed by interacting with water?

3. Chemical properties of amphoteric oxides

Experiment 3

Add a small amount of zinc oxide (ZnO) powder into three test tubes with a spatula. Next, add 2 mL of the solutions to three test tubes: water to the first, hydrochloric acid to the second, and concentrated sodium hydroxide solution to the third.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (gas evolution, dissolution, precipitation) in each test tube?
- ✓ Make an equation for the reactions, and name all the substances formed.
- ✓ Conclude about the properties of amphoteric oxides.

4. Obtaining water-insoluble bases

As we have already seen (*on Lecture 1 experimental demonstration*), oxides of alkali and alkaline earth metals react with water to form soluble bases (alkali). Transition metals and their oxides practically do not interact with water, so the bases of such metals are obtained indirectly, for example, from salts of this metal.

Experiment 4

Pour 2-4 mL of copper (II) sulfate solution into a test tube, then add an equal volume of concentrated sodium hydroxide solution. Observe the formation of a precipitate.

Write in the workbook:

- ✓ Is there a change in color or state of aggregation (precipitation)?
- ✓ Make a reaction equation, please name all the substances formed.
- ✓ Conclude the properties of basic oxides.

5. Thermal stability of bases

Heat the test tube with the reaction products from **Experiment 4** on a gas burner before the boiling point (**performes by the teacher**). Observe the change in the color of the precipitate.

Write in the workbook:

- ✓ Why did the color change occur?
- ✓ Make a reaction equation, please name all the substances formed.
- ✓ Conclude the thermal properties of bases.

LAB 2. ACIDS, SALTS

TASKS FOR SELF-PRACTICE

1. Write the formulas of the anhydrides of the following acids: H_3BO_3, HNO_3, HNO_2, H_2CrO_4, $HMnO_4$, H_2SO_4, H_2SO_3, H_3PO_4. Name the acids and the corresponding anhydrides.

2. Write the equations of the stepwise dissociation of the following acids: H_3BO_3, H_2SiO_3, H_3PO_4, H_2S, H_2CrO_4, HNO_3, and determine the valency of the acid residues.

3. Write the formulas of the following salts: magnesium sulfate, sodium sulfide, calcium nitrite, ammonium sulfate, calcium hydrogen sulfide, sodium dihydrogen orthophosphate, magnesium hydrogen sulfite, aluminum hydroxide sulfate, calcium hydroxide nitrate, copper (II) hydroxide carbonate, and iron (III) dihydroxide sulfate.

4. Name the salts: MgS, $Ca(HS)_2$, K_2HPO_4, $FeOHCl_2$, $Al(HSO_4)_3$.

5. Write the equations of the reactions that can be used to perform the following transformations:

$$Al \rightarrow Al_2(SO_4)_3 \rightarrow Al(OH)_3 \rightarrow AlOHCl_2 \rightarrow$$
$$\rightarrow AlCl_3 \rightarrow Al(OH)_3 \rightarrow Na_3AlO_3.$$

<u>The student should know:</u>

Definition of acid (with examples), the nomenclature of names, types of acids (binary acids, oxyacids, organic acids, strong-weak). Know the methods of obtaining acids, typical reactions of interaction with bases, and metal oxides.

Definition of salts, types of salts (acidic, neutral, basic), and their typical reactions, be able to give examples, and know the nomenclature of salts.

EXPERIMENTAL PART

1. Obtaining medium salts

Experiment 1.1

Pour 1-2 ml of sodium hydroxide solution into a test tube, then add a few drops of indicator (phenolphthalein). Observe the color. Add hydrochloric acid drop by drop until the color changes.

Write in the workbook:

- ✓ What does the change in the color of the indicator indicate?
- ✓ Make an equation for the reaction of neutralization, name all the reaction products.
- ✓ Conclude the neutralization reaction and the formation of neutral salts.

Experiment 2.1

Pour 1-2 ml of sodium orthophosphate solution into a test tube and add an equal amount of calcium chloride solution. Observe the formation of a white precipitate of neutral salt.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (gas evolution, dissolution, precipitation)?
- ✓ Write down your observations in your workbook.
- ✓ Write down the reaction between two salts, name all the reaction products.
- ✓ Conclude the reaction between two salts.

2. Production and properties of acidic salts

Experiment 2.2

To the test tube from the previous experiment **(Experiment 2.1)**, add orthophosphoric acid drop-by-drop, until the precipitate dissolves.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Record your observations in your workbook.
- ✓ Write down the equation for the reaction of forming an acidic salt, please, name all the reaction products.
- ✓ Conclude about the solubility of acidic salts.

Experiment 2.3

Pour about half of the test tube with lime water (calcium hydroxide solution), then bubble carbon dioxide (IV) through the lime water. Observe the formation of a white precipitate – calcium carbonate. Continue to bubble the gas until the precipitate dissolves due to the formation of an acidic salt from the middle. Add a few drops of alkali (sodium hydroxide or lime water), and observe the reverse transformation of the acidic soluble salt into an insoluble middle.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (gas evolution, dissolution, precipitation)?
- ✓ Write down your observations in your workbook.

- ✓ Write down the equations for the reaction of forming a neutral salt, then convert to acidic salt. Please name all the reaction products.
- ✓ Conclude the transformation of acidic into neutral salts.

3. Production and properties of basic salts

Experiment 3

Pour 2 mL of copper (II) sulfate solution into two test tubes. Add 2 mL of concentrated sodium hydroxide solution into the first test tube, then add 2 mL of diluted NaOH solution into the second test tube. Note the different colors of the precipitates. Write down the equations for the formation of neutral and basic salts, and name formed substances.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (gas evolution, dissolution, precipitation)? Explain the color change in each of the test tubes.
- ✓ Write down your observations in the workbook.
- ✓ Draw up the equations for the reaction of neutral salt formation, acid salt formation. Please name and note all reaction products.
- ✓ Conclude the transformation of acid into neutral salts.

LAB 3. REACTIONS IN ELECTROLYTE SOLUTIONS, IONIC-MOLECULAR EQUATIONS

TASKS FOR SELF-PRACTICE

1. Write the equation of the dissociation of zinc hydroxide in acidic and alkaline media.

2. Write the equation of electrolytic dissociation: a) aluminum sulfate; b) sodium hydrogen carbonate; c) copper(II) hydroxide nitrate.

3. Which of the following electrolytes are strong: zinc sulfide, sulfitic acid, ferric(II) hydroxide, sodium carbonate? Write the expressions of the first and second dissociation constants for sulfitic acid.

4. Write the molecular, ionic-molecular, and abbreviated ionic-molecular equation of the interaction between iron (II) sulfide and hydrochloric acid.

5. Write the molecular and complete ionic-molecular equation, which corresponds to the abbreviated one: $Cu^{2+} + S^{2-} = CuS\downarrow$.

The student should know:

What are ions, electrolytes, weak and strong electrolytes, ionic dissociation, degree of dissociation, dissociation constant, be able to write ionic equations in full and in short forms.

EXPERIMENTAL PART

1. Reactions with the formation of precipitates

Experiment 1

Pour 1 mL solutions of sodium sulfate, magnesium sulfate, and zinc sulfate into three test tubes, then add a few drops of barium chloride solution into each test tube.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Record your observations in the workbook.
- ✓ Write molecular, ionic-molecular, and abbreviated ionic-molecular equations of the reactions.

2. Reactions with the formation of gas or sparingly soluble substances

Experiment 2.1

Take a test tube, add 1 spatula of powdered calcium carbonate, and add 1 mL of hydrochloric acid drop by drops. Observe the formation of the gas.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Record your observations in the workbook.
- ✓ Write molecular, ionic-molecular, and abbreviated ionic-molecular equations of the reactions.

Experiment 2.2

Take a test tube, pour 1 mL of dilute hydrochloric acid solution, and add 1 mL of sodium carbonate solution.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Record your observations in the workbook.
- ✓ Write molecular, ionic-molecular, and abbreviated ionic-molecular reaction equations.

3. Reactions with the formation of weakly dissociated substances (weak electrolytes)

Experiment 3

Add a small amount of solid sodium acetate into a test tube and add 1-2ml of dilute hydrochloric acid. Observe (by smell) the formation of acetic acid.

Write in the workbook:

- ✓ Is there a change in color and/or state of aggregation (evolution of gas, dissolution, precipitation)?
- ✓ Record your observations in the workbook. Write molecular, ionic-molecular, and abbreviated ionic-molecular equations of reactions.

4. Shifting ionic equilibrium (*Le Chatelier's* principle)

Experiment 4

Pour 1-2 mL of diluted acetic acid into a test tube, and add 2-3 drops of litmus indicator. Note the color of the solution. Pour half of the contents of the test tube into another test tube and add a small amount of solid sodium acetate. Stir the contents of the test tube with a glass rod and compare the color of these test tubes.

Write in the workbook:

- ✓ Compare the color of the solutions in the two test tubes.
- ✓ Record your observations in a workbook.
- ✓ Write molecular, ionic-molecular, abbreviated ionic-molecular equations of reactions.
- ✓ Explain your observations by applying *Le Chatelier's* principle to ionic equilibrium.

LAB 4. DETERMINATION OF THE PH OF SOLUTIONS

TASKS FOR SELF-PRACTICE

1. The concentration of hydroxide ions is 10^{-4} mol/l. Calculate the concentration of Hydrogen ions, pH, and pOH of the solution.

2. Choose solutions with pH = 3:

a) 0.001M NaOH; b) 0.001M H_2SO_4;

c) pOH = 11; d) 0.3M HCl.

3. 2 l of the solution contains 7.3 g of HCl. Calculate the molar concentration of acid in the solution, the concentration of ions $[H^+]$ and $[OH^-]$, and the pH of the solution.

4. Choose the solution with the maximum pH value:

a) 0.1M HNO_3; b) 0.1M CH_3COOH;

c) 0.01M LiOH; d) 0.1M $Ca(OH)_2$.

5. Choose acidic solutions:

a) pH = 8; b) pH = 3;

c) pOH = 6; d) pOH = 2;

e) [OH-] = 10^{-2} mol/l.

The student should know:

Definition of pH and pOH, the concept of dissociation, degree of dissociation, dissociation constant, ion product of water, be able to calculate pH and pOH from the concentration of the corresponding ions, understand the principle of operation of the pH-meter, and examples of practical application of the pH.

EXPERIMENTAL PART

There are various methods for determining the pH of a solution. In this Lab, we will get acquainted with the most common ways: a) determining the pH with **test strips**, b) **by a pH-meter**, and c) **by formulae**, using known concentrations of acid/base solution.

Latmus Paper test strips can be used to determine pH with an accuracy of ±1 pH unit or more accurate test strips, up to ±0.1 pH, as shown on Fig 2, b, were *few different indicators* is used. 2. A pen pH-meter allows for an accuracy of ±0.1 pH, while lab-grade equipment has an accuracy of ±0.001 pH or better.

a) b)

Fig.2. pH test strips, with an accuracy of a) ± 1 and b) ± 0.5 units.

1. Determination of pH of solutions

Students have got four beakers with the following reagents:

- ✓ 0.1M solution of strong hydrochloric acid,
- ✓ 0.1M solution of weak acetic acid
- ✓ 0.1M solution of weak base ammonium hydroxide
- ✓ 0.1M solution of strong base sodium hydroxide.

Experiment 1

1. Pour 20 ml of the first reagent into a measuring cup, use a glass rod to transfer a drop of the solution to a test strip, and compare with the reference color scale. Write results to the table.
2. Turn on the pH-meter, immerse the electrode in the solution, wait about 1 minute to establish the value, and record the readings in the table.
3. Calculate the pH of the solution by formulae. Write results to the table.
4. Repeat steps 1-3 for the next reagent solution.

Write in the workbook:

- ✓ Record the results in the table:

Table 1. Determination of pH of solutions

Electrolyte	pH value		
	Test strip	*pH-meter*	By formulae/concentration
HCl, 0.1M			pH = –lg C_M
CH_3COOH, 0.1M			pH =0.5·(pK_a – lg C_M)
NH_4OH, 0.1M			pH =14 – 0.5·(pK_b – lg C_M)
NaOH, 0.1M			pH = 14 + lg C_M

N.B.

pK_a (CH_3COOH) = 4,76 pK_b (NH_4OH) = 4,74

(were p = – lg, *a* – acid, *b* – base).