

# Using the Cloud-oriented Virtual Chemical Laboratory VLab in Teaching the Solution of Experimental Problems in Chemistry of 9th Grade Students

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**Abstract.** The article discusses the importance of the skills of primary school students to solve experimental problems in chemistry and the conditions for the use of virtual chemical laboratories in the process of the formation of these skills. The concept of “experimental chemical problem” was analyzed, classifications were considered, and methodological conditions for using experimental chemical problems in the process of teaching chemistry were described. The essence of the concept of “virtual chemical laboratories” is considered and their main types, advantages and disadvantages that define the methodically reasonable limits of the use of these software products in the process of teaching chemistry, in particular, to support the educational chemical experiment are described. The capabilities of the virtual chemical laboratory VLab to support the process of solving experimental problems in chemistry in grade 9 have been determined. The main advantages and disadvantages of the virtual chemical laboratory VLab on the modeling of chemical processes necessary for the creation of virtual experimental problems in chemistry are analyzed. The features of the virtual chemical laboratory VLab, the essence of its work and the creation of virtual laboratory work in it are described. The results of the study is the development of a set of experimental tasks in chemistry for students in grade 9 on the topic “Solutions” in the cloud-oriented virtual chemical laboratory VLab.

**Keywords:** experimental tasks in chemistry, virtual chemical laboratories, solutions.

## 1 Introduction

Electronic learning tools are widely used in the educational process of teachers from different disciplines, but it is in the chemistry lessons of their use that is perhaps the most appropriate. A chemist should not so much accumulate knowledge as discover something new. Electronic learning tools, in particular clouds oriented virtual chemical laboratories, can bring the process of knowledge of chemical laws to a qualitatively new level: to facilitate the involvement of all participants in the educational process in active search and research activities, self-expression; to ensure the formation of critical

and associative thinking, imagination; promote the development of the ability to argue, analyze data, justify and argue the conclusions.

One of the important means of developing chemical thinking and checking the strength of learning is the experimental tasks in chemistry. However, now this kind of tasks is practically not used in the educational process at school, but it is used at high levels olympiads in chemistry. One of the reasons for this phenomenon is the lack of time for the organization of experimental tasks, the risk associated with possible harm to the health of students, the insufficient provision of schools with chemical reagents and equipment, and the like. Virtually all of the above problems can be solved with the help of appropriate means of information and communication technology (ICT).

That is why the purpose of our work is to determine the capabilities of the virtual chemistry laboratory VLab to ensure the possibility of solving experimental problems in chemistry and developing the appropriate set of virtual computer problems.

To achieve this goal it is necessary to solve the following tasks:

- to analyze the concept of “experimental task in chemistry” and find out the meaning and place of experimental tasks in the school chemistry course;
- analyze the opportunity of using clouds-oriented virtual chemical laboratories in pre-profile training;
- find out the advantages and disadvantages of using the Virtual Lab in the creation and implementation of virtual chemistry labs;
- apply the results of research in practice in the form of creating a set of virtual experimental chemistry problems for students in grade 9.

To solve the tasks set in the work, the following research methods were used:

- analysis of methodological, pedagogical and chemical literature, Internet sources;
- analysis of teachers’ experiences;
- systematization and synthesis;
- modeling of chemical processes in the virtual chemical laboratory Virtual Lab.

## **2 Theoretical foundations of using cloud-oriented virtual chemical laboratories in teaching the solution of experimental problems in chemistry**

### **2.1 Experimental tasks as a means of teaching chemistry**

Chemistry is an experimental science, and that is why a chemical experiment in pupil’s develops a chemical style of thinking – the ability to understand the essence of chemical processes, their significance and how to manage them. The modern pedagogical process should be aimed at the child’s mastering the very techniques, methods, ways of thinking, that is, the student must master the technology of carrying out appropriate mental actions.

From the studies of famous teachers, didactists, psychologists, the formation of learning abilities is a complex process, the essence of which is to create opportunities

for performing work related to learning. In particular, the competence-based approach focuses on the acquisition of skills, experience, and practical application of acquired knowledge in chemistry. Therefore, despite the fact that the content of educational material in chemistry is directed to students mastering practical skills in working with substances, provides for observation and experiment, solving computational and experimental problems, establishing causal relationships, the use of algorithms helps students in solving a number of problems, over time, develop into the ability to solve life problems [15].

Thanks to the educational chemical experiment, students acquire practical experience in obtaining facts and their preliminary synthesis at the level of empirical concepts, concepts and laws. Under such conditions, the chemical experiment performs the function of the method of educational cognition, thanks to which new connections and relationships are formed in the consciousness of the student, personal knowledge is formed. It is because of the educational chemical experiment that the activity approach to teaching chemistry is effectively implemented. But it is impossible to carry out an experiment without first considering the result and not drawing up an action plan. That is why the experimental problem solving as a kind of simulator are offered to students.

The solution of chemical problems is an important aspect of mastering the knowledge of the basics of chemical science. The inclusion of tasks in the educational process allows the following didactic teaching principles to be implemented: 1) ensuring the independence and activity of students; 2) the achievement of the strength of knowledge and skills; 3) implementation of the connection of learning with life; 4) the implementation of polytechnic chemistry training, vocational guidance [21].

The ability to solve problems develops in the process of learning, and this skill can be developed only in one way – to solve problem constantly and systematically.

Algorithmic actions of students in solving chemical problems in most cases is not at all in strict adherence to a specific procedure, guaranteed to lead to the correct result. But the learning algorithm, according to M. M. Savchin, first of all means a certain variability of actions in search of the optimal way to solve the problem [15]. In many cases, this variation in the course of isolation is inherent in experimental chemical problems.

Among the diverse arsenal of methods of teaching chemistry, a special place is occupied by the solution of experimental problems in the classroom and the fulfillment of home experiments by students. Experimental tasks are tasks whose solution is accompanied by experiments. M. S. Pak considers experimental chemical problems as a type of cognitive tasks in chemistry [14, p. 162]. In contrast to laboratory work and practical exercises, students solve experimental tasks on their own without additional instructions from the teacher. All students' work in solving experimental problems is built on an attempt to apply acquired theoretical knowledge and practical skills to solve a specific problem in conditions close to real ones.

In its content, the experimental tasks can be directed to:

- observation and explanation of phenomena;
- preparation of solutions;

- execution of characteristic and qualitative reactions;
- recognition of substances.

You can also give another classification of experimental problems, according to which they are based on the activities of:

- familiarization with the properties of substances;
- determining the qualitative composition of substances;
- separation of mixtures;
- phased conversion of substances;
- determination of the quantitative composition of substances, mixtures
- release of substances from the mixture in its pure form;
- quantitative problems on the laws of conservation of mass of substances and the stability of their composition;
- preparation of solutions of a given concentration and determination of the concentration of an unknown solution [1].

To solve any experimental problem, a certain sequence of actions is characteristic:

1. drawing up an experiment plan (action algorithm), within which it is necessary to determine which specific question should be answered and which experiments should be carried out for this purpose;
2. the implementation of the experimental part;
3. the formulation of conclusions about the possibility of using the obtained experimental data to answer the question posed, and reasonable evidence or refutation of the initial assumptions [8].

Experimental problems in chemistry can be solved by the following methods: analytical-synthetic, hypotheses, and attempts. But mainly experimental problems in chemistry are solved by the analytical-synthetic method.

The use of experimental tasks in the educational process allows us to solve a number of important pedagogical problems, in particular, to develop students' creative abilities and the ability to analyze the condition of the problem and select an experimental model, improve the skills of applying the laws of chemistry, and the like [1].

The choice of problem solving method depends on the students having theoretical knowledge and practical skills.

Pupils should be taught to choose a rational way of solving experimental problems. At the same time, students form the ability to analyze tasks, make plans for decisions and reports.

In the class of studying new educational material, experimental tasks can be used in various aspects: at the beginning of a lesson, to nominate a problem and arouse students' cognitive activity; during the lesson – in the study of the chemical properties of substances or substances; at the end of the lesson – to consolidate new knowledge.

In the lesson of consolidation of knowledge and the formation of practical skills, experimental tasks can be used at its different stages in order to teach students to apply their knowledge to solve practical problems, or to study the device and the principle of the device and acquire the ability to use it.

In the lessons of generalization and deepening of knowledge, solutions to experimental problems are organized to specify the content of physical concepts and to establish new methods for measuring physical quantities and establishing new information about the phenomenon studied.

In knowledge control lessons, solving experimental problems will help test students' ability to apply knowledge in familiar and unfamiliar situations, analyze facts and take a critical look at the results of a chemical experiment.

At the lessons of control and accounting of students' knowledge, as well as at the lessons of generalization and deepening of knowledge, a significant part of the lesson and even the entire lesson can be devoted to solving experimental problems. It is advisable to solve complex problems, in particular the combined ones, which require knowledge of various sections of chemistry.

The ability to solve problems is one of the main indicators of the level of students' mastery of knowledge in chemistry. However, students often cannot solve a difficult task, although they discover the knowledge of theoretical material, they know the definition, the basic formulas, the laws, and solve standard problems. The reason is that students are used to solving typical tasks, and problems of an unknown type cause them to be confused [10]. The tasks are useful, as a result of which students get new information or acquire skills, tasks that make you think logically, based on theoretical knowledge, but with a creative approach. These criteria are exactly the experimental tasks.

Selecting experimental tasks, it is necessary to take into account the age of students, their psychological characteristics and the level of knowledge in chemistry. Experimental tasks are highly effective when students have sufficient knowledge of the relevant material. The form of the problem statement should be convenient for solving at each stage of the lesson.

Today there are many manuals and periodicals in which you can find a selection of experimental problems on a particular topic and are ready to solve them. However, the current trend is the introduction of information technology training in the process of formation of the subject competence of students. It can be said with confidence that students' performance of experimental tasks using information and communication technology tools will be more interesting for students and more productive [1].

## **2.2 Virtual chemical laboratories as a tools of teaching chemistry**

When studying chemistry at school, one of the most difficult tasks facing the teacher is to familiarize students with real chemical objects and processes. This difficulty is due to the simplicity and lack of equipment in school chemical laboratories, restrictions on the use of certain chemical compounds in them, reduction of time to study certain topics in curricula, and the like.

A solution to these problems is to use information and communication technologies in the educational process, in particular spreadsheets [16; 17], augmented reality tools [12; 18] and virtual chemical laboratories (VCL) [11].

According to O. V. Trukhin, a virtual laboratory "is a hardware-software complex that allows experiments to be carried out without direct contact with a real installation

or in the complete absence of it. In the first case, we are dealing with a so-called laboratory setup with remote access, which includes a real laboratory, software and hardware to control the installation and digitization of the data, as well as means of communication. In the second case, all processes are modeled using a computer” [19].

So, under the virtual laboratories understand two types of software and hardware systems:

- laboratory installation with remote access (remote laboratories);
- software that allows to simulate laboratory experiments – virtual laboratories (in the narrow sense) [19].

The advantages of virtual chemical laboratories are:

- no need to purchase expensive equipment and reagents. Due to inadequate funding, many school chemical laboratories have old equipment installed that can distort the results of experiments and serve as a potential source of danger for students. Also, in addition to equipment, consumables and reagents are required, the cost of which is quite high. It is clear that computer equipment and software are also expensive, but the universality of computer equipment and its wide distribution and availability somewhat compensate for this disadvantage;
- the possibility of modeling processes, progress or observations of which are fundamentally impossible in the laboratory. Modern computer technologies by means of visualization on the monitor screen provide an opportunity to observe processes that cannot be observed in real conditions without the use of additional equipment, for example, due to the small size of the observed particles or difficult to achieve conditions (ultra high or ultra low temperatures, pressure, etc.);
- the possibility of penetrating into the subtleties of processes and observing the details of a phenomenon that occurs on a different time scale, which is important for processes occurring in a fraction of a second or, on the contrary, last for several years;
- no immediate danger to the lives and health of students. Safety is an important advantage of using VCL, especially in cases where the work involves, for example, the use of hazardous chemicals or devices associated with the use of high temperatures, pressures, electric current, etc;
- saving time and resources for transferring the results into electronic format;
- the possibility of using VCL for informal education and distance learning, is to ensure the possibility of performing laboratory work in chemistry for the lack of access to school laboratories, including when working with children with limited physical abilities;
- the development of skills to find the optimal solution, the ability to transfer the real problem in model conditions and vice versa.

Perhaps the disadvantage of using virtual chemical laboratories is that the model objects created by the computer are completely supplanted by the objects of the child in the real world. But working with sign systems is the basis of analytic-synthetic activity, that is, thinking does not exist outside of abstraction and symbolization. Also,

significant shortcomings of the VCL are the limited information that they transmit to various users' senses, and the inability of students to develop skills in working with real laboratory objects.

By the way of visualization, laboratories are distinguished using two- and three-dimensional graphics and animation.

Also, virtual laboratories are divided according to the way they represent knowledge of the subject area. In one case, virtual laboratories are based on individual facts, limited to a set of pre-programmed experiments. They represent a specific set of laboratory studies, compiled in accordance with the curriculum. Experiments in such virtual laboratories can only be viewed. Intervention in their course is impossible [7, p. 131-132].

Otherwise, conducting virtual laboratory experiments is based on a mathematical model of a real chemical process. Such virtual laboratories provide for the possibility of changing the experimental conditions within certain limits and adequately reflecting these changes in its results. Licensed versions of such programs, as a rule, provide an opportunity to create your own laboratory work. Such virtual laboratories contribute to independent knowledge of the world by students and provide an opportunity for the teacher to realize their creative abilities regarding the chemistry learning process.

The development of VCL, based on mathematical modeling of real chemical processes, is more complex and time-consuming, but significantly expands the possibilities of their application [7, p. 132].

Examples of such VCL are Crocodile Chemistry, Model ChemLab [9] and Virtual Lab (VLab) [4].

Any of the VCL is only a model of the real world, and therefore, like any other model, there is a certain limitation, simplicity. Different virtual chemical laboratories have a different level of simplicity compared to real chemical laboratories: different in detail graphic display of objects, lack of transmission of smells and tactile sensations of objects manipulated in a virtual environment [13].

In our opinion, the most appropriate for use in the process of solving experimental chemical problems is such virtual chemical laboratories that allow the user to actively intervene in the course of the process, to offer and experimentally test their own algorithms for solving. The only virtual chemical laboratory that meets these requirements and is freely available is the Virtual Lab, so we decided to implement the development of a set of experimental problems in it.

### **3 Methodical basis for the development of a set of experimental tasks in chemistry for students in grade 9 in the cloud-oriented virtual chemical laboratory VLab**

#### **3.1 Features of the virtual chemical laboratory VLab**

The most accessible of the modern VCL, providing the ability of the user to intervene in the course of a virtual experiment, as well as the possibility of developing their own virtual laboratory work is the Virtual Lab (VLab).

The goal of the VLab virtual chemistry lab, which is a ChemCollective product, is to create flexible, interactive learning environments in which students can approach chemistry as practicing scientists.

ChemCollective began with work on the IrYdium Project's Virtual Lab in 2000. The project was to create training exercises designed to provide interactive, interesting materials that link chemical concepts with the real world.

The project leader is Dr. David Yaron, Associate Professor of Chemistry, Carnegie Mellon. Most of the original exercises included in this virtual lab were developed by a team at Carnegie Mellon, including D. Yaron, experienced software engineers, student programmers, educational consultants, and editors [3].

Virtual chemical laboratory Virtual Lab is free to install, use and distribute. It can be used both online (by running the virtual lab plugin from the ChemCollective website using any browser) or locally by downloading the installation files and installing the program on the computer.

Virtual Lab can also be integrated with the Moodle system using a special plugin. This makes it possible to apply the individual tasks of the virtual lab directly to the specific topics of the Moodle course [11].

In each assignment of the virtual chemical laboratory VLab, access to chemical reagents, which may include general purpose reagents or compounds specific for a given job, as well as chemical glassware (beakers, conical flasks, graduated cylinders, pipettes, volumetric flasks of various volumes, also a 50 ml burette and pin-up plastic glass) and equipment (Bunsen burner, weighing hook and scales).

A separate panel of the program window is designed to provide information about a substance or a mixture: name, volume, state of aggregation, amount of substance (mol or g), concentration (mol/l or g/l), spectrometer data, pH meter, and thermometer. Some of these tools can be disabled if this is required by the condition of the problem, which is solved in this virtual laboratory (see Fig. 1).

All actions with dishes and substances in it are performed in drag and drop mode, that is, by simply dragging objects with the left mouse button. The same operations, as well as some specific actions, can be carried out through the menu that appears when you click on an object with the right mouse button [20].

The essence of the program is to download certain tasks and solve them experimentally or calculated with the subsequent experimental verification of the result. There are no restrictions on the number of attempts to perform experience on restrictions on the use of certain quantities of reagents and materials.

Using the exercises of the virtual laboratory VLab, according to its developers, provide the ability to:

- help students who have missed class work in the laboratory to do an experiment from their personal computer, without the need to do work under the supervision of a teacher;
- supplement current work and homework on paper with exercises that allow students to use chemical concepts to design and perform their own experiments;
- monitor the correctness of the assignments of students (students use a virtual laboratory to check the results of their own calculations or qualitative forecasting



- without risk to their own health);
- to supplement the demonstration experiment conducted in the classroom (teachers first carry out a demonstration in the classroom so that students can see the actual chemical processes, and the students then study the chemical system and processes independently, guided by the tasks in the virtual laboratory).

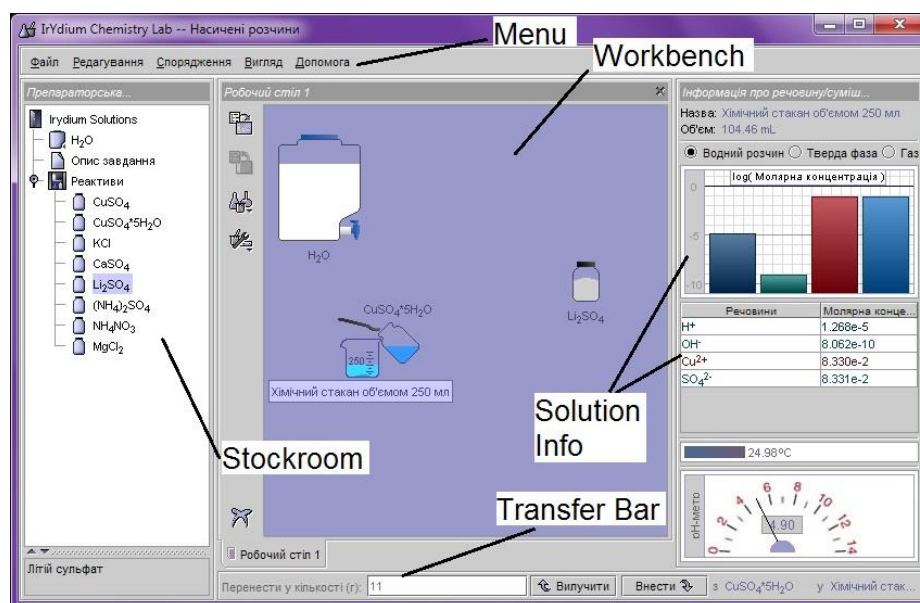


Fig. 1. VLab window with virtual laboratory work

Virtual Lab software currently includes more than 50 exercises and tasks that are designed to assimilate chemical concepts, mainly related to the study of solutions and processes in them: moths, stoichiometry and limiting reagents (tasks for excess), density, dilutions, dissociation constant, acids and bases, thermochemistry, solubility, chemical equilibrium, redox processes [2].

The installation package of Virtual Lab contains thirteen launch files for this program in different languages, among which Ukrainian since 2014 has been. Running the local version of the program, as well as the old online version, required the presence of a Java plug-in. Recently, this plugin has been blocked by most browsers and antivirus programs, it requires separate settings on the system, therefore, in 2017, the HTML5 version of the VLab was launched on the ChemCollective website in 2017, which currently supports only three languages: English, Spanish and Italian.

On the old version of the ChemCollective site (<http://collective.chem.cmu.edu>), you can download a special task editor, the Virtual Lab Authoring Tool, which allows you to both modify existing tasks and develop your own from scratch for the local version of the program.

In the task set, included in the standard version of the VLab program, most of the virtual works are oriented to a level higher than the level of the basic school – core, or

college and university. The content of a certain number of tasks is structured in such a way that all of them are full-fledged study and research tasks [11]. Our work was thus aimed at developing tasks that can be classified as experimental chemical tasks on the “Solutions” topic, were coordinated with the curriculum, and at the same time were available for primary school students in terms of complexity.

### 3.2 Creation of laboratory work in a virtual laboratory VLab

In order to create your own laboratory work, you need to understand how this virtual lab works. The virtual laboratory is launched by running the default.xml file (or default\_uk.xml for the Ukrainian version), which is located in the assignments directory. This is the default virtual lab file. This file contains individual properties of the program’s working area: the availability of tools (thermometer, pH meter, windows with information about the chemical composition of substances and solutions) and the available modes of substance transfer (accurate transfer, transfer of rounded quantities and realistic transfer). These tools and transfer modes can be either available for work, all or some of them can be turned off depending on the needs of the task scenario. Also in this file are the ways in which the working area of the program is filled with reagents, possible physicochemical processes with their participation, a description of the work task, and the like. These default paths lead to files that are in a subdirectory with the same name as the control xml file — that is, the files to work with, are guided by the default\_uk.xml file, are in the default\_uk directory (the path to it is in the program directory assignmetns / default\_uk). The directory referenced by the control xml file contains typically four files:

- filesystem.xml – contains information about the solutions (reagents) planned for use in this virtual laboratory work and the dishes in which they are contained, their volume or mass, and a brief description of this reagent (name, concentration, etc.);
- reactions.xml – contains information on all possible (planned) chemical reactions with a specific set of substances in this virtual laboratory work;
- species.xml – contains information on all substances available in this virtual laboratory work and their properties (color, state of aggregation, thermodynamic parameters, molar mass, etc.);
- problem\_description.html – contains a text description of the task and instructions for performing virtual lab work.

VLab versions higher than 2.1.0 may also contain the spectra.xml file, which contains the spectral characteristics of the substances that will be displayed in the photocolimeters window, if it is available for use in this work.

Other laboratory works are started on the same principle, only the control xml-files are located in separate thematic sub-subdirectories in the subdirectories of language localization, for example, the control xml-file of the localized Ukrainian work “Determining the solubility of  $\text{CuCl}_2$  at different temperatures” CuClSolu.xml is located along the way assignmetns / problems\_uk / solubility.

The list of control xml files with the path to them and a brief description of the work is in the ProblemIndex\_uk.xml file (ProblemIndex.xml for the standard English

version) in the root directory of the program. From this file that the list of laboratory works available for execution is called up via the menu “File” → “Load task”.

Any of these files can be edited using Notepad (it is important to save changes in the UTF-8 encoding) or any xml file editor. But a more optimal option is to use the special editor Virtual Lab Authoring Tool. There are several options for creating a new laboratory work: from scratch, editing and saving the default xml file, and based on another work. The second way is faster and more rational, since it allows partially (and in some cases, possibly completely) using those reagents, equipment and other necessary parameters of work, since they have already been entered and are guaranteed to work. To make this change, open the control xml file in the Virtual Lab Authoring Tool editor and select “Save As ...” in the “File” menu, specify the new file name and its location. In our case, it was the School catalog, which we created specifically for this set of works. A directory with content files is automatically generated.

Henceforth control xml-file in the editor Virtual Lab Authoring Tool need to edit.

The editor window has several tabs, each of which changes a certain part of the work data (see Fig. 2):

- General – contains fields for entering the title of the work, the last name of the author and a brief description of the content of the work.
- Permissions – contains two tabs: Viewers to specify the tools for viewing the properties of substances and their chemical composition will be available during the work; and Transfer Bars to determine the substance transfer parameters available in the job.
- Species – contains tools for creating and editing substances needed in this work. In addition to the formula, the molar mass and the name of the substance, the state of aggregation, as well as its coloring parameters, its standard enthalpy of formation and entropy are obligatory characteristics – these data will be used to simulate chemical reactions between the corresponding substances.
- Reactions – contains tools for planning the flow of physicochemical processes, by defining reactive particles as reagents or reaction products and setting appropriate coefficients.
- Stockroom – provides the ability to create and edit the contents of the “Stockroom” in the virtual laboratory – add cabinets, dishes with reagents, accompanying files (description of the task, etc.).

At the end of the work in the editor Virtual Lab Authoring Tool you need to save the changes and make the created work in the registry of works so that it becomes available for use. To do this operation, a block is created in the ProblemIndex\_uk.xml file (editing with a notepad or xml editor):

```
<DIRECTORY name="Назва блоку лабораторних робіт">
  <PROBLEM url="assignments/problems_uk/school/назва
файлу.xml">
  <TITLE>Назва роботи</TITLE>
  <AUTHOR>Автори</AUTHOR>
  <DESCRIPTION>
```

Короткий опис завдання роботи  
 </DESCRIPTION>  
 </PROBLEM>  
 </DIRECTORY>

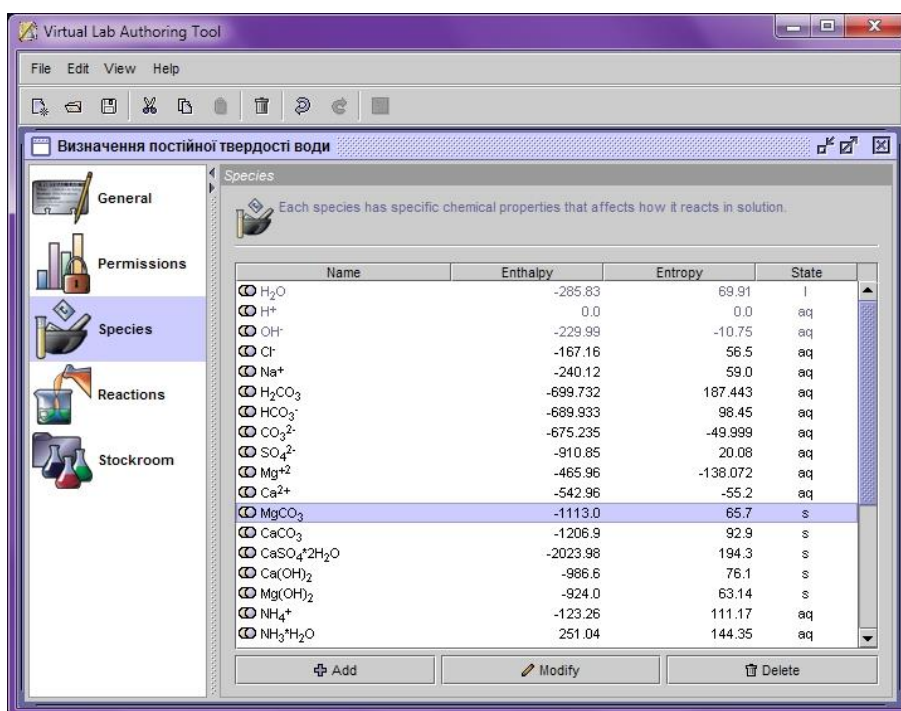


Fig. 2. Editor Virtual Lab Authoring Tool window

A block limited by <DIRECTORY> ... </ DIRECTORY> tags can contain as many individual works as desired, each of which is separated by <PROBLEM> ... </ PROBLEM> tags.

Created or edited works become available after the next program launch.

### 3.3 A set of experimental chemical tasks in a virtual chemistry lab VLab for use in school

To test the possibilities of using the virtual chemistry laboratory Virtual Lab to support the implementation of experimental tasks in chemistry, we chose the topic “Solutions” studied in grade 9.

The chemistry curriculum in grade 9 [5] provides for the solution of experimental problems on this topic, as well as the reaction equations using solutions with a certain mass fraction of the solute; use of demonstration experiments (thermal phenomena during dissolution: dissolution of ammonium nitrate and concentrated sulfuric acid in

water, studies of substances and their aqueous solutions for electrical conductivity, exchange reactions between electrolytes in aqueous solutions) conducting laboratory studies (detection of hydrogen and hydroxide ions in solutions, established approximate pH values of water, alkaline and acidic solutions (sodium hydroxide, hydrochloric acid) using a universal indicator, pH studies search and cosmetic products, the exchange reaction between electrolytes in aqueous solutions, accompanied by precipitation, the exchange reaction between electrolytes in aqueous solutions, accompanied by the evolution of gas, the exchange reaction between electrolytes in aqueous solutions, followed by water absorption, the detection of chloride, sulfate and carbonate ions in solution) carrying out practical work (ion exchange reactions between electrolytes in aqueous solutions) of executing a home experiment (preparing colloidal solutions (jelly etc.)), preparation and protection of educational projects (“Electrolytes in modern accumulators”, “Growing of crystals of salts”, “Production of solutions for provision of medical assistance”, “Research of soil pH of the area”, “Investigation of the influence of acidity and alkalinity of soils on plant development”, “Research pH of atmospheric precipitation and their influence on various materials in the environment”, “Investigation of natural objects as acid-basic indicators”, “Investigation of the pH of the mineral water of Ukraine”).

The most important and most complex parts of this topic are the solubility of substances, its dependence on various factors. Saturated and unsaturated, concentrated and diluted solutions. Thermal phenomena accompanying the dissolution of substances, dissolution as a physical and chemical process, the concept of hydrates, electrolytic dissociation etc. Therefore, experimental tasks should be directed to the study of precisely these substantive parts of the topic.

After analyzing the technical and visual capabilities of the Virtual Lab, we determined that it would be most appropriate to create virtual experimental tasks related to the dissolution process (its energy and quantitative characteristics), the dissociation process of substances in a solution and determine its pH, as well as the use of some qualitative reactions, indicators and the like. The tasks associated with the study of the properties of colloidal solutions, the flow of certain exchange reactions, the extraction of crystals, the study of the analytical effects of qualitative reactions associated with the formation of precipitation cannot be realized either due to the limited possibilities of modeling chemical phenomena in the VLab and due to the limitations of visual accompaniment (for example, to conduct qualitative reactions with the formation of sediment among the equipment in the VLab there are not enough test tubes, and the presence of sediment and its color become noticeable in a glass x on the desktop of the virtual laboratory only in quantities of a few grams or more, does not comply with the principles of qualitative chemical analysis).

Based on all the above, we have created a trial set of experimental problems on the topic “Solutions”, which contains seven tasks. The works contain instructions for solving problems and a number of questions that students need to answer.

For example, the laboratory work “Precursor” suggests that the student present himself as a laboratory technician and carry out dilutions of concentrated sulfuric acid, which is on the list of precursors. The task is to prepare equal volumes of solutions with the indicated concentrations.

In the work “Separation of salt mixture”, it is necessary to separate the mixture of crystalline potassium chlorate and sodium chloride by recrystallization of potassium chlorate, based on the difference in the solubility of these salts. The task contains the order of actions that will help to perform the work. The purpose of this task is to familiarize students with the methods of purification and separation of substances, the dependence of the dissolution of salts on temperature.

To demonstrate the preparation of saturated solutions, you can use the work “Preparation of saturated solutions of various chemical compounds”. Here the student will be able to prepare solutions by changing the temperature, and on the basis of the data obtained, construct curves for the concentration of a saturated solution of a substance on temperature. The aim of the work is to study the change in the solubility of substances from temperature, the formation of skills in the preparation of saturated solutions, the analysis of the experimental data.

The study of thermal effects of dissolution can be carried out in the work “Thermal effects of dissolution”. In the description, it is reported that during the dissolution of the substance various physical and chemical processes take place with both the solute and the solvent. One of the external indicators that can be easily fixed is the thermal effect observed when various substances are dissolved. The task is to investigate the thermal effects of dissolution of various crystalline compounds in water and to draw appropriate conclusions and assumptions regarding the processes leading to the occurrence of these effects. The purpose of the work is to form an understanding of the thermal phenomena that accompany the process of dissolution and test them in practice, consolidating knowledge about exo- and endothermic processes.

The overwhelmingly developed tasks contain a sufficient number of hints so that the student can experiment in a virtual laboratory independently, for example, on a home computer, and some of the tasks are quite realistic to reproduce in a real school chemistry laboratory, given the time and possibilities (in this case problem solving in a virtual laboratory can be used as a training option to verify the correctness of theoretical calculations and repeat the order needed imyh action).

A set of these laboratory works are posted on the website of the Department of chemistry and methods of learning chemistry at the KSPU (<https://kdpu.edu.ua/khimii-ta-metodyky-ii-navchannia/tsikava-khimiia/dlia-vseznaiook/5928-virtualna-khimichna-laboratoriia.html>) with the aim of further introducing schools into the educational process and receiving feedback on improving the quality and expansion of this set.

## 4 Conclusions

1. Experimental tasks in chemistry is a separate type of chemical problems, the solution of which is necessarily accompanied by the practical implementation of a chemical experiment.
2. Experimental chemical tasks, as one of the varieties of experimental activity of students in chemistry, is an integral part of an effective teaching and educational process, and led to the methodological feasibility of their use in various types of lessons, at different stages of a lesson and in extracurricular work.

3. Pre-profile chemistry training contains a significant amount of experimental activity of students, and one of the ways to overcome the contradiction between the need to carry out a training chemical experiment and the lack of sufficient time, necessary equipment and reagents, the use of virtual chemical laboratories — special computer programs that make it possible to simulate the physical chemical phenomena or to conduct experiments without direct contact with a real set th or the complete absence thereof.
4. The advantages of the virtual chemistry laboratory Virtual Lab should include free distribution, the ability to edit existing and create your own laboratory work (tasks), the availability of the Ukrainian version, user-friendly design, minimum system requirements, the possibility of active user intervention during the virtual laboratory work.
5. Mathematical model of chemical processes in the virtual chemical laboratory. The Virtual Lab uses the thermodynamic characteristics of substances and calculates the parameters of the equilibrium state in various systems (mainly solutions), applying the dependence of the isobaric-isothermal potential and the equilibrium constant. This determines the simplicity of the process of creating models of equilibrium processes for this virtual laboratory and their adequacy to real processes.
6. The main drawbacks of the Virtual Lab program is the use of corresponding thermodynamic parameters in modeling chemical processes only as a first approximation, the lack of opportunities to model the kinetic effects of chemical processes, the inability to adequately simulate the processes occurring with the release of gas compounds and the like.
7. Considering the possibilities and advantages of the virtual chemical laboratory Virtual Lab and analyzing the chemistry curriculum for the 9th grade, it was found out that the most appropriate development of a set of experimental chemical problems for schoolchildren in the topic “Solutions” is one of the main ones in the 9th grade and before profile training in general. The developed set currently consists of seven tasks and implies its further expansion and improvement taking into account the results of its practical implementation in the educational process of schools.

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