USING THE VIRTUAL CHEMICAL LABORATORY VLAB IN TEACHING CHEMISTRY OF 9TH GRADE STUDENTS

Pavlo Nechypurenko
PhD, Associate Professor[1]
acinonyxleo@gmail.com

Tetyana Selivanova
PhD, Associate Professor[1]
vitro090@gmail.com
[1]*Department of Chemistry and Methods of Learning Chemistry*
Kryvyi Rih State Pedagogical University
54 Gagarin ave., Kryvyi Rih, Ukraine, 50086

Abstract: The article discusses the importance of the skills of 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 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 are 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, VLab, 9th grade students.

1. Introduction

E-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. E-learning tools, in particular 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 [1–3].

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 [4]. Virtually all of the above problems can be solved with the help of appropriate means of ICT.

That is why the purpose of our work is to determine the capabilities of the virtual chemistry laboratory VLab [5–8] 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:

a) find out the advantages and disadvantages of using the Virtual Lab in the creation and implementation of virtual chemistry labs;

b) apply the results of research in practice in the form of creating a set of virtual experimental chemistry problems for students in grade 9.

2. Methods

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.

3. Results

In order to create your own laboratory work in VLab, you need to understand how this virtual lab works. The virtual laboratory is launched by running the default.xml file (or 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:

1) filesystem.xml – contains information about the solutions, 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;

2) reactions.xml – contains information on all possible chemical reactions with a specific set of substances in this virtual laboratory work;

3) species.xml – contains information on all substances, available in this virtual laboratory work and their properties;

4) problem_description.html – contains a description of the task and instructions for performing the 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 photocolorimeters 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 $CuCl_2$ 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 are in the ProblemIndex_uk.xml file (ProblemIndex.xml for the English version) in the root directory of the program. It is 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 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 the control xml-file in the editor Virtual Lab Authoring Tool needs to edit. The editor window has several tabs, each of which changes a certain part of the work data:

– 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; 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;

– 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="Workshop/Problem Set Name">
    <PROBLEM url="assignments/problems_uk/school/filename.xml">
        <TITLE>Problem Name</TITLE>
        <AUTHOR>Authors</AUTHOR>
        <DESCRIPTION>
            Workshop/Problem description
        </DESCRIPTION>
    </PROBLEM>
</DIRECTORY>
```

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.

4. Discussion

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 [9, 10] provides for the solution of experimental problems on this topic; use of demonstration experiments (thermal phenomena during dissolution, studies of substances and their aqueous solutions for electrical conductivity, exchange reactions between electrolytes in aqueous solutions) conducting laboratory studies (detection of hydrogen ions 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 conducting a home experiment (preparing colloidal solutions (jelly and 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 physico-chemical process, the concept of crystalline hydrates, electrolytic dissociation, degree of electrolytic dissociation. 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 Virtual Lab and due to the limitations of visual accompaniment (for example, to conduct qualitative reactions with the formation of sediment among the equipment in the Virtual Lab 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 him/herself 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. The correctness

of the concentrations of the prepared solutions can be checked, focusing on the concentration of H^+ and SO_4^{2-} ions.

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 energy (thermal) effects of dissolution can be carried out in the work "Thermal effects of dissolution". 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 exothermic 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 [11] with the aim of further introducing schools into the educational process and receiving feedback on improving the quality and expansion of this set.

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