Exploring the Interplay between Pedagogy and Psychology: A Structural Analysis

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Abstract. This paper is a didactic project to teach the topic "*Chemical bond and structure of substance – didactic aspects*", that aims to help students understand the most important notions, laws and theories. In the process of mastering the material of the topic, skills should be improved for students to make inter-subject communications with physics and mathematics based on the application of knowledge about electrons, ions, and nucleus of an atom. Students should more often be given the opportunity to analyze the composition of substances and make conclusions about the nature of chemical bonds, compare the structure of atoms, simple and complex substances, establish a relationship with properties, and predict the type of crystal lattice based on the properties of substances, so they will be able to develop logical thinking skills. When studying the topic, ideas about the relationship of opposites, about the transition of quantitative changes to qualitative ones will be further developed. Having finished the lesson students must deepen their knowledge about ionic and covalent chemical bonds, establish differences between polar covalent bond and nonpolar covalent bond, recognize substances with different bond type, develop mobility of thought, modeling, generalization and abstracting ability, cultivate the analytical spirit and the power of synthesis, use chemical terminology while presenting information on chemical connection.

Keywords: *crystal lattice, covalent nonpolar and polar bonds, ionic bond, electronegativity, spatial structure, valence angle.*

Rezumat. Acest articol prezintă un proiect didactic pentru predarea temei "*Legătura chimică și structura substanţei – aspecte didactice*", care își propune să îi ajute pe studenţi să înţeleagă cele mai importante noţiuni, legi și teorii. La studierea subiectului, ar trebui îmbunătăţite abilităţile pentru ca elevii să poată realiza legătura cu fizica și matematica prin aplicarea cunoștinţelor despre electroni, ioni și nucleul atomului. Dezvoltând gândirea logică, elevilor li se oferă oportunitatea de a analiza compoziţia substanţelor și de a face concluzii despre natura legăturii chimice, pentru a compara structura atomică a substanţelor simple și compuse, stabilind legătură cu tipul reţelei cristaline bazată pe proprietăţile substanţelor. Vor fi dezvoltate cunoștinţele cu privire la contradicţii, despre trecerea schimbărilor cantitative la cele calitative. La sfârșitul lecţiei, elevii trebuie să-și aprofundeze cunoștinţele privind legăturile chimice ionice și covalente, să stabilească diferenţele dintre legătura covalentă polară și nepolară, să recunoască substanţele cu diferite tipuri de legături, să dezvolte mobilitatea gândirii, modelarea, generalizarea și abilitatea de abstractizare, cultivă spiritul analitic și puterea de sinteză, pentru a utiliza terminologia chimică în prezentarea informaţiilor despre conexiunea chimică.

Cuvinte chee: *reţea cristalină, legătură covalentă polară și nepolară, legătură ionică, electronegativitate, structură spaţială, unghi de valenţă.*

Introduction

While studying this topic, there should be a deepening of knowledge among students about the periodic law and the system of chemical elements of D. I. Mendeleev. Firstly, it is considered the simple and complex substances properties dependence on the structural features of atoms of elements and chemical bonds nature in molecules and crystals. Secondly, there should be formed the concepts of electronegativity, oxidation state, covalent (polar and nonpolar) and ionic bonds, types of crystal lattices. The application of these concepts is impossible without mastering the skills to compose electronic formulas of compounds formed using chemical bonds of different types and to determine the degree of elements oxidation by the formulas of compounds.

In the process of mastering the educational material of the topic, skills should be improved for students to make inter-subject communications with physics and mathematics based on the application of knowledge about electrons, ions, and the nucleus of an atom. Students should more often be given the opportunity to analyze the composition of substances and make conclusions about the nature of chemical bonds, compare the structure of atoms, simple and complex substances, establish a relationship with properties, and predict the type of crystal lattice based on the properties of substances, so they will be able to develop logical thinking skills. When studying the topic, ideas about the relationship of opposites, about the transition of quantitative changes to qualitative ones will be further developed. It is important for the teacher to draw the students' attention to the mutual influence of matter particles. A substance is a system in which the properties as a whole are not the sum of properties of its individual elements: the mutual influence of the structural particles of a substance, leading to a redistribution of electron density, determines new properties. It is important to form ideas about the mechanism of formation of covalent and ionic bonds [1].

Why to form chemical bonds? The basic answer is that atoms try to reach the most stable (lowest-energy) state that they can. Many atoms become stable when their valence shell is filled with electrons or when they satisfy the octet rule (by having eight valence electrons) [2]. If atoms don't have this arrangement, they will "want" to reach it by gaining, losing, or sharing electrons via bonds.

Students must learn to predict the type of chemical bond between the elements atoms, to determine the type of crystal lattice by the properties of the substance and vice versa.

In the traditional explanation of chemical bonds types, the study begins with a consideration of covalent bonds, then, introducing students to the concept of "electronegativity", gives an idea of covalent nonpolar and polar bonds and, finally, talk about ionic bonds [3].

But another, more generalized approach is possible, in which students are introduced to all types of communication at the same time. We will reveal more about both approaches.

Covalent bond

In the traditional presentation of the material, before starting to identify specific chemical bond formation mechanism, students are introduced to how the problem of elements compounds formation was solved, what is the main theory position of chemical bonds.

It is worth mentioning, that the doctrine of chemical bonding is one of the central problems of chemistry, the solution of which has passed a number of stages in its development from the ideas about the presence of atoms "loops" and "hooks" with which they connect to knowledge about the electrostatic nature of the chemical communication and drawing up different types formation models of chemical bonds. Modern research methods make it possible to experimentally determine the spatial arrangement of atomic nuclei in the molecules of substances, i.e. to reveal the distance between them (the bond length), to determine the valence angles, the shape of the molecule or unit cell of the crystal, it is possible to experimentally determine the energy of the chemical bond. All these facts indicate the real existence of different chemical bond types.

The teacher can talk about how, based on experimental information, scientists create models that reflect the structure of substances, and suggest (hypotheses) about the mechanism of formation of chemical bonds. Modeling (Fr. *"modele"* means model, prototype) is a certain object properties reproduction specially created for study. Since a direct study of the chemical bond and the structure of substances is not always possible, models make up for it. Further development of knowledge allows us to improve the models necessary for scientific research.

A mechanism is a model of a process. On the basis of certain experimental data and theoretical principles, a hypothetical idea of intermediate phases connecting the initial and final state of the object is built. The process is mentally divided into separate stages, some of which are recorded in the experiment, some are developed theoretically. Knowledge of phenomena mechanism allows you to control them. Revealing the chemical bonds formation mechanism, the teacher will use idealized models of covalent and ionic bonds [4].

Before starting considering the covalent bonds formation mechanism, it is necessary to refresh the knowledge about the structure of atoms acquired while studying physics and chemistry. Students must answer a number of questions:

1. What particles does an atom consist of?
2. What is the charge of an electron?
3. What electrons are called paired?

The teacher should remind students that electron pairing is due to the special properties of these particles, that more than two electrons cannot combine.

Then, it is important for students to focus on the noble gases atoms chemical inertness explanation, which is that the atoms of inert elements are characterized by the completeness of the outer electronic layer. Obviously, the reason for the ability of atoms of all other elements to connect with each other is the incompleteness of the outer layer of their atoms. This information is used further while studying covalent bonds formation mechanism.

Using the example of a hydrogen molecule, the teacher explains the formation of a covalent bond due to the partial overlap of electron clouds when two hydrogen atoms come together, due to which two electrons belonging to these atoms are combined into a common electron pair, i.e. mate. Between the nuclei, a region of increased electron density is formed, due to which the atomic nuclei are kept nearby. In this case, the incomplete layers of these atoms turn into complete ones. When explaining, it is useful to use diagrams, application models, and drawings from the series “Chemical bond. The structure of substances" The location of valence bonds at a certain angle is illustrated by the example of the structure of a water molecule.

Students are further told that there is sufficient evidence of a chemical bond. Firstly, it is proved that the distance between the nuclei of hydrogen atoms in a molecule is less than the sum of two radii of an atom. Secondly, it was found that the overlap of electron clouds (pairing of electrons belonging to different atoms) is an energetically favorable process in which energy is released. This energy characterizes the strength of the chemical bond. Consequently, a molecule is energetically more stable than a single atom, its potential energy is less than the sum of the energies of the atoms that form it.

When considering other examples of various nonmetal compounds molecules formation, it is necessary to explain how to compose electronic and structural formulas of substances. In this case, the corresponding entries can be made out in the form of a table.

There are two basic types of covalent bonds: polar and nonpolar. In a **polar covalent bond**, the electrons are unequally shared by the atoms and spend more time close to one atom than the other spends. Because of the unequal distribution of electrons between the atoms of different elements, slightly positive (δ+) and slightly negative (δ–) charges develop in different parts of the molecule.

In a water molecule (above), the bond, connecting the oxygen to each hydrogen is a polar bond (figure 1). Oxygen is a much more **electronegative** atom than hydrogen, meaning that it attracts shared electrons more strongly, so the oxygen of water bears a partial negative charge (has high electron density), while the hydrogens bear partial positive charges (have low electron density) [5].

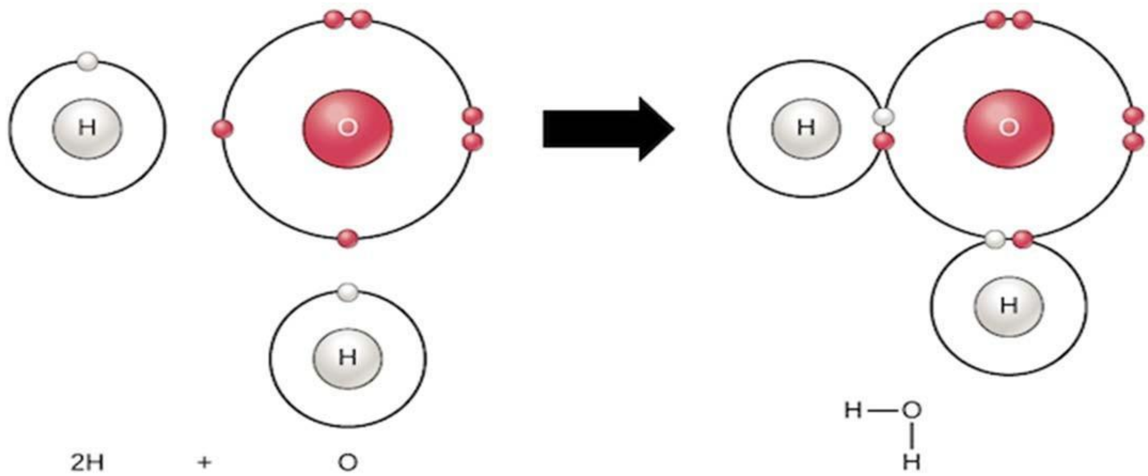

Figure 1. The formation of polar covalent bond.

Studying the structure of matter opens up opportunities for a wider use of intersubject communications with physics. Students perform actions in a certain sequence:

1. Note that the formation of a chemical bond occurs between atoms (a statement of the level of organization of the substance at which the phenomenon occurs);
2. Establish that a chemical bond is formed as a result of the motion and collision of atoms (motion is a characteristic state of atoms);

3. Find out that the formation of chemical bonds occurs due to the electrons in the atoms (explanation at a deeper (electronic) theoretical level;

4. Make a conclusion that a chemical bond is formed due to pairing of electrons (an explanation of the formation of covalent bonds).

In accordance with the algorithm, students can be offered assignments to repeat the studied material. Students analyze the following questions:

1. What particles are part of the molecules?
2. Why can not a chemical bond be formed between atoms located at a great distance from each other?
3. Under what conditions can a chemical bond occur?
4. What particles that make up the atoms cause the formation of a chemical bond between them?
5. What general property of electrons underlies the formation of bonds between atoms?

The study of polar covalent bonds should be based on the concept of electronegativity. Students should pay attention to the following points:

1. Electronegativity is a property of atoms, which manifests itself in conjunction with the atoms of another element;
2. Electronegativity of elements - the ability of atoms to pull back on themselves the total electron density in compounds, depends on the charge of the nucleus and the radius of the atom;
3. Based on the position of the element in the periodic system, one can judge the magnitude of the nuclear charge and the radius of the element atom (in comparison with the elements adjacent to the table), and, therefore, about their electronegativity (also in comparison with elements of the same subgroup or one and the same period). If the elements are in different subgroups and periods, when comparing them, a number of electronegativity should be used.

Most chemical elements have average values of electronegativity: in their nature two opposite qualities are combined - metallicity and non-metallicity.

While comparing the electronegativity of element atoms in substances Cl_2, HCl, HI, NH_3, students should determine in which cases there is a greater or lesser shift in the total electron density that forms the chemical bond [6].

Ionic bonds

The shift of the electron density cannot occur infinitely, so, in the case of the combination of alkali metal atoms and halogens, a common electron cloud is practically not formed. The electrons of metal atoms outer layer completely transfer to the electron shells of halogen atoms. Electron pairing occurs in the halogen atom [7].

Students should note the stability of ions, explaining this by the fact that a significant amount of energy is released during their formation.

The stability of ions can also be explained from the standpoint of their outer electron shells structuere.

It is necessary to pay attention to the fact that a compound with an ionic bond manifests itself as a unity of particles with opposite properties. Students can independently identify this: a difference in the structure of the outer electronic layers of metal and nonmetal atoms, a difference in the processes of electron transfer by metal atoms and their attachment by nonmetal atoms, and a difference in the signs of resulting ions charge.

When one atom loses an electron and another atom gains that electron, the process is called **electron transfer**. Sodium and chlorine atoms provide a good example of electron transfer [8]. Sodium (Na) only has one electron in its outer electron shell, so it is easier (more energetically favorable) for sodium to donate that one electron than to find seven more electrons to fill the outer shell. Because of this, sodium tends to lose its one electron, forming Na^+. Chlorine (Cl), on the other hand, has seven electrons in its outer shell. In this case, it is easier for chlorine to gain one electron than to lose seven, so it tends to take on an electron and become Cl^- (figure2).

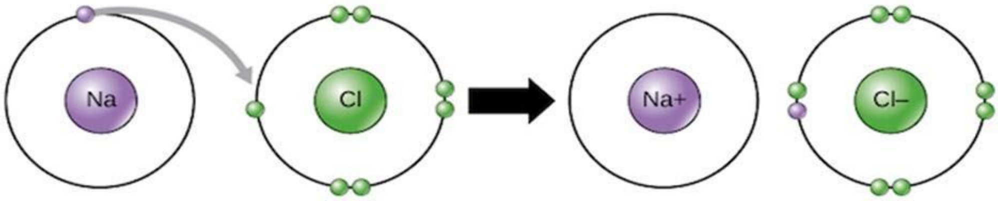

Figure 2. The formation of ionic bond.

When sodium and chlorine are combined, sodium will donate its one electron to empty its shell, and chlorine will accept that electron to fill its shell. Both ions now satisfy the octet rule and have complete outermost shells. Because the number of electrons is no longer equal to the number of protons, each atom is now an ion and has a +1 (Na^+) or –1 (Cl^-) charge.

In general, the loss of an electron by one atom and gain of an electron by another atom must happen at the same time: in order for a sodium atom to lose an electron, it needs to have a suitable recipient like a chlorine atom [9].

Generalization and systematization of knowledge about the types of chemical bonds

The study of ionic bonding should be based on the repetition of covalent bonding and electronegativity features. When analyzing the chemical bond in hydrogen chloride, it should be noted that although the electron density in the molecule is shifted to the chlorine atom, the electron cloud nevertheless combines both atoms and is common to them. What will happen to this electron cloud if the bond is formed by atoms of elements that differ significantly in electronegativity, for example, halogen atoms and alkali metals? Students can assume that in this case there will be an almost complete displacement of the region of increased electron density towards a more electronegative atom.

The concept of the degree of oxidation should be given after students understand how they determine the numerical charge value of an ion in a compound. Noting that even in compounds of typical metals and typical non-metals, for example, NaCl, NaI, the real ion charge does not have an integer value, it is necessary to note the conventional designation of ion charges in the form of integers, i.e. about a kind of idealization, formalization of reception. In compounds with a polar bond due to a shift in the total electron density to a more electronegative element, a certain charge on atoms is also formed. Conventionally, as for ionic compounds, one can indicate the sign and number of charge units. The oxidation state is a conditional charge, which is attributed to the chemical elements that make up the substance, based on the assumption of chemical bond ionic nature in it. It indicates the number of partially (or completely) displaced electrons from one atom to another in the compound, for example, $Na^{+1}Cl^{-1}$, $Ca^{+2}I_2^{-1}$, $Si^{+4}Cl_4^{-1}$, $Al_2^{+3}O_3^{-2}$.

It should be noted that the expression "electron displacement" is conventional. It is necessary to remember the phenomenon of dissociation, during which the ions acquire a real integer charge. In this case, the charge of a freely existing ion is designated differently: the charge sign is placed after the number (the number 1 is not written with the sign):

$$NaCl \leftrightarrow Na^+ + Cl^-; \quad Al_2(SO_4)_3 \leftrightarrow 2Al^{3+} + 3SO_4^{2-}.$$

Mastering the concept of “degree of oxidation” allows you to organize work on the development of the ability to determine the degree of oxidation by the formulas of compounds, make formulas and names of binary compounds in accordance with the rules of international nomenclature.

A generalized approach to the study of chemical bonds is that at the beginning they give an idea of all types of chemical bonds, introduce the concept of "electronegativity". In the future, they organize work to comprehend the basic theoretical provisions on various types formation methods of bonds, the assimilation of electronegativity concepts, covalent polar and nonpolar, ionic bonds and the formation of skills to apply the acquired knowledge in the preparation of electronic and structural formulas of substances and determine chemical bonds types in compounds.

The main tasks to implement a generalized approach to the study of chemical bonds are as follows: disclosure of chemical bonds formation essence between atoms; the concepts formaiton about the types of chemical bonds, electronegativity; clarification of the meaning of electronic and structural formulas; the formation of students conviction in the cognizability of the world of substances; development of general skills to analyze, highlight the main thing in the studied educational material, draw conclusions [10].

During the embrace, it is important to emphasize that, entering into a chemical interaction, the atoms of the elements acquire a stable electronic structure with a complete electronic layer due to pairing of unpaired electrons belonging to the same or different atoms. Next, we consider various mechanisms of the formation of stable electron shells upon joining:

1) atoms of the same nonmetal chemical element (covalent nonpolar bond);
2) atoms of various chemical elements of nonmetals (covalent polar bond) and, finally;
3) atoms of metals and non-metals (ionic bond).

At the same time, students are introduced to the concept of chemical elements atoms electronegativity and a number of electronegativity. It should be reported that, knowing the comparative electronegativity of the elements, it is possible to determine the type of chemical bond in various compounds and to emphasize the difference between the covalent polar bond and the covalent nonpolar one, to characterize the ionic bond in comparison with the covalent polar bond.

At the next stage, it is necessary to organize work on the further assimilation and comprehension of the main theoretical bonds, master the concepts of various chemical bonds types, master the "electronegativity" concepts, "covalent bonds", "ionic bonds", their use to determine the type of bonds in the specified compound. Students should be able to develop the ability to compose electronic circuits to form substances with various types of bonds, explain their mechanism, write down electronic and structural formulas of ionic and covalent compounds, and predict the type of bond between the atoms of the proposed chemical elements.

In these lessons, the main place is given to individual work of students, including work with the textbook. Assignments are projected through the projector or given to students in the form of worksheets (pre-prepared assignment cards) [11].

The teacher takes a certain time for each task, during which the students manage to discuss emerging issues with each other, clarify the answers to the most difficult tasks, and carry out mutual control. The teacher carefully monitors the progress of independent work and assists students when needed.

It is possible to organize short-term verification work on the options in order to clarify the results of the assimilation of the studied concepts.

Further, when considering the concept of “degree of oxidation”, students learn to determine the degree of oxidation by the formula of a substance, apply this concept, making up the formulas of binary compounds. It is important that they indicate the type of chemical bond.

When summarizing the knowledge about the types of chemical bonds, special attention should be paid to the most important characteristic of all types of bonds — the bond is formed due to the interaction of the electrons of the outer electronic layer and the appearance of a stable molecule as a result of this interaction [12].

It makes sense to deal with the student an example showing how the type of chemical bond changes during the formation of various fluorine compounds.

It is important to emphasize that the boundaries between the types of chemical bonds are arbitrary. In nature, any extremes are always connected by a series of transitions. Isolation of extreme variants, consideration of phenomena in a “pure” form allows one to more fully understand their features and imagine the middle members of the series in which these extremes are combined. Students themselves should give examples proving the absence of sharp boundaries between the types of chemical bonds, the conventionality and relativity of their classification [13]. When working with models, it should be recalled that they reflect the object incompletely and idealize the idea of it. Further, the general conclusion will be the conclusion about the recognizability of the chemical bond and the structure of matter using physical and chemical methods, which allows us to understand the causes of substances diversity and improve the practice of controlling the transformation of substances.

A round-up task is carried out by focused homework on tasks involving the ability to apply knowledge.

It should be noted that if the student finds it difficult to answer questions, then he must revise the corresponding material in the textbook (the necessary paragraphs are indicated) and find the answers to the questions in it).

Most substances whose properties are studied by students have a crystalline structure. The study of the crystalline structure of substances should be based on intersubject communications. Crystals are macro bodies, their properties, such as hardness, melting point, boiling point, etc., depend on the structure due to the characteristics of the particles that make up the crystal (molecules, atoms, ions). The combination of particles in a crystal depends on the structure of the electron shells of atoms and the properties of electrons. It turns out, as it were, three steps while considering the properties of a substance: macro level, molecular or atomic, electronic. The laws operating at each subsequent level can serve as a justification of the laws operating at the previous level. For example, the hardness and refractoriness of a substance can be explained by the atomic or ionic structure of crystals, the presence of forces acting between them.

As a result of the discussion, it must be concluded that the structural particles of a substance affect each other. Their mutual influence is accomplished through the redistribution of electronic proton and leads to the fact that the properties of the whole (molecule, crystal) differ from the elements properties of their structure, as they are caused not only by their nature, but also by the interaction. Micro- and macro-forms of matter differ in properties because they are different systems: they consist of different elements, are connected by different forces [14]. It is important to pay attention to the chain of causal relationship that one characteristic of a substance, being the cause of another, is a consequence of the third. In a simplified form, this can be expressed as follows:

atomic structure of chemical elements → type of chemical bond between them → type of crystal lattice → physical properties of matter cause → effect cause → effect cause → effect.

It can be noted that the properties of structural particles in a crystal or molecule in a bound state differ significantly from the properties of particles in a free state. It is enough to compare the properties of sodium, chlorine and sodium chloride; sulfur, oxygen and sulfur dioxide. To confirm the difference between the "part" and the "whole", we can give an example. If zinc and copper were taken as separate atoms, then when they interacted with acid solutions, they would easily be converted into ions. The energy effect of such a reaction for zinc would be + 283 kJ/mol, and for copper + 274.5 kJ / mol. But from practice it is known that in the form of a simple substance, copper does not displace hydrogen from aqueous solutions of acids, and zinc displaces. This contradiction can be explained if we take into account the interaction of particles forming the crystal lattices of zinc and copper. The energy of this interaction is different: when separating zinc atoms from its crystal, it consumes 130.5 kJ/mol, and copper 339 kJ/mol. Therefore, the interaction of a simple zinc substance with an aqueous acid solution comes with the release of 152,5 kJ / mol. The calculated thermal effect of the reaction between a simple substance - copper and an aqueous solution of acid is – 64,5 kJ/mol, i.e. such a process will not occur spontaneously [15].

When considering the structure of the crystal lattices of substances, one can use either factory-made ball-rod models or home-made ones made of balls ("tight packing"). Using models makes it possible to bring schoolchildren's ideas closer to reality.

It should be noted the fact of particles motion in the nodes of the crystal lattice near the position of stable equilibrium. In this case, interaction between neighboring particles is carried out, the momentum and energy are exchanged. On models and grown crystals, you can see that the cell structure is transmitted in the contours of large crystalline formations: the angles ratio and the edges lengths of the unit cell is repeated. So, it can be noted that the internal microstructure features are manifested in the external.

Students should clearly understand that the term "molecule" is not applicable to substances of ionic and atomic structure. The composition of sodium chloride can be written as Na_nCl_n. Such a record reflects an idealized composition. In real conditions, crystals can have any defects (the absence of one or another ion in the site of the crystal lattice, replacing it with another, close in radius). The simplified NaCl formula reflects the approximate ratio of the numbers of Na^+ and Cl^- ions in an ionic crystal.

While studying crystal lattices, it is necessary to systematize knowledge and to achieve concretization of their new examples.

In conclusion, it should be noted that to know the ability of substances spatial structure, their use in the study of physical methods indicate the relationship of sciences. It is necessary to pay attention to the practical use of the acquired knowledge.

Checking the mastery of the topic. The formative test or a short-term verification work can be carried out within the studying process.

After studying the topic under consideration, a final test is provided. With this control act, it is necessary to verify that students have achieved general results.

Training materials by the type of crystal structure are monitored during the current audit on this topic and more fully - after studying the following topics.

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