Modern materialistic understanding of the "energy" notion and the method of its systemic evaluation in chemicals

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Abstract. It was shown that the traditional approaches to understanding the notion of "energy" as a work or a physical quantity are outdated. For example, R. Feynman noted that "today's physics does not know what energy is." Therefore, even now, some researchers believe that "by and large, the concept of energy… is artificial, because unlike matter, of which we can say that it exists, energy is the fruit of human thought." In contrast to these ideas, the authors showed that energy, like matter, objectively exists in various forms (energy continuum), which differ in structure, and is able to perform different types of work, to determine the forms of interaction and movement of matter in various material systems (substances, material bodies and megamaterial systems). A new scientific foundation for systematization and quantitative evaluation of energy characteristics of chemical compounds was proposed. It is based on a comprehensive assessment of contribution of chemical compounds' composition and chemical bond type in line with a chemical bond's unified model and the "System of chemical bonds and compounds" (SCBC). As a result of using this basic scientific innovation, the symbiosis of Mendeleev's periodic table of atoms (composition – property) and SCBC (composition - chemical bond and structure – property) was realized for the first time. The foundation was laid for creating a database on systemic digitalization and evaluation of energy stored in various chemicals (natural gas, coal, oil, peat, wood, etc.) and the most effective ways of extracting it from these.

1. Introduction

The crisis in the evolution of scientific knowledge of the XXI century is becoming more and more obvious today. This is due to the presence of two major global problems in the development of scientific knowledge today. First, the problems of scientific knowledge fragmentation and the development of a single universal view of the structure of the universe, as well as the clarification of the fundamental causes of the diversity of phenomena and objects of the Earth and the Universe as a whole, have become particularly acute in science, education and natural science in general. The second is the growing contradiction between the accumulated separate empirical information ("scattered" in around 17,000 different scientific disciplines) and a significant part of the traditional, but outdated scientific paradigms [1-3]. That is, knowledge today is fragmented like a tree into separate branches, but the roots and the single unifying material trunk are not visible. Progress in the development of modern scientific approaches to the study of matter, its varieties, and the structure of the universe as a whole has also slowed down, in part due to attempts to equate scientific and
materialistic approaches with mythology and religion (for example, in theology). However, the difference is obvious and these approaches are fundamentally opposite. Scientific materialism is based on the principle of the knowability of the universe (nature), while mythology is based on agnosticism, that is, on its unknowability. The reason for this difference is demonstrated by the radically different answer to the question: "What is primary: matter or consciousness?". For scientific materialism, matter is primary. Consciousness is secondary because it is only a property of matter, not any matter, not stagnant and not any living thing, but only having a highly developed (as in an educated person) material organ – the brain. Today it is necessary to raise materialistic knowledge to a new integral level, taking into account the individual achievements of modern science in various (differential component) branches of knowledge, as well as educating our schoolchildren and students.

For power engineering universities, the concept of "energy" is of particular importance, but the meaning of its traditional definitions needs to be clarified and evolutionarily developed. However, the meaning of the concept of "energy" is traditionally presented not as an objective material reality, but only as a hypothetical physical quantity that can perform work, etc., that is, as a "property", but it is not clear whose property.

The aim of this work is to consider and clarify the meaning of the concept of "energy" in the framework of modern views on structure and properties of matter as the most important fundamental concept of natural science and to consider the option of a systemic assessment of chemical energy through a system of chemical bonds and compounds (SCBC) in the form of a "Chemical triangle".

2. Exposition
Historically, for a long time, instead of the term "energy", the term "living force" was used, introduced by I. Newton. For the first time in history of the concept of "living force", the meaning of "energy", without uttering this word, was put by Julius von Mayer in his paper "Remarks on the forces of inorganic nature", published in 1842. The special term "energy" was introduced in 1807 by the English physicist Thomas Young and denoted a quantity proportional to the mass and the square of the velocity of a moving body. In science, the term "energy" in its modern sense was introduced by William Thomson (Lord Kelvin) in 1860. The features of the properties of this phenomenon, as the "law of conservation and transformation of energy", was introduced into scientific circulation by F. Engels, this allowed all types of energy to be measured by using single unit.

In his lectures on physics, delivered in 1961-1963 at the California University of Technology, the famous American physicist R. Feynman noted [4] that within the framework of the law of conservation of energy "there is a certain quantity called energy, which does not change under any transformations occurring in nature." "This statement itself is very, very abstract; it is essentially a mathematical principle..." It is important to understand that the physics of today does not know what energy is." Further in 2001 I. V. Plachkov et al. (Ukraine), when asked what the concept of "energy" is, noted that "by and large, the concept of energy, the idea of energy, is artificial and created specifically to be the result of our thoughts about the world around us." He further states, 'that unlike matter, about which we can say that it exists, energy is the fruit of man's thought, his 'invention', constructed in such a way that it makes possible to describe various changes in the surrounding world and at the same time to talk about the permanence, the preservation of something that was called energy...".

It is hardly possible to agree with this, since energy, according to the authors of this paper, is an objective material reality that is widely used by humanity in solving problems of its life support (heat, electricity, etc.). And if so, then it is necessary to understand in what material form energy exists in the universe.

3. Discussion
The concept of "energy" is traditionally interpreted in different ways, including using traditional, but no longer accurate enough for the XXI century definitions. For example, energy (E) is a physical quantity that shows what work a body (or several bodies) can do, or the energy of a body. In another
version, **energy** (Greek: ἐνέργεια - action, activity, force, power) is a scalar physical quantity that is a single measure of various forms of movement and interaction of matter, a measure of the transition of the movement of matter from one form to another. First, within the framework of the fourth (integral-differential) stage of the development of scientific knowledge and the paradigm of the multilevel organization of substance and matter [1-3], it is questionable whether it is correct to call any energy a "physical quantity" (after all, there are chemical and other types of energy). It is more correct to use a more precise and universal scientific concept of "material quantity". Secondly, energy is not just an abstract quantity that characterizes body's ability to work or a measure of various forms of motion and interaction of matter. These definitions are vulnerable due to the fact that "energy" in them is presented simply as a "property" of matter without revealing its material essence. After all, the property of energy is precisely the ability to bind discrete varieties of matter into various substances (atoms, molecules, cells) and material bodies, to produce work, etc. Therefore, for a consistent materialist, energy is an objective reality (thermal, electrical, nuclear, etc.) in the form of field forms (energy continuum) of matter and one of the two (together with mass) most important components and characteristics of material objects as a whole. It is this energy, together with mass, that determines, within the framework of the law of conservation of mass – energy and wave-particle dualism, the features of the modern paradigm of multi-level structural organization and properties of substances and matter in general (fields -substances - material bodies - megamaterial systems) [2, 3]. The contribution of the outstanding Russian scientist M. V. Lomonosov to the discovery of the law of conservation of mass is known. In 1905, the famous physicist A. Einstein showed that between the mass \( m \) of a body (substance) and its energy \( E \), there is the following relationship:

\[
E = mc^2,
\]

(1)

where \( c \) is the speed of light in a vacuum.

In this case, equation (1) is associated [5], not just with the energy \( E \) of any material body, but with the bond energy \( E_{\text{bond}} \) of elements in an atomic nucleus. Moreover, we usually consider the specific bond energy (the average bond energy per nucleon), which depends on the mass number \( A \) and the larger it is, the more stable the nucleus. For light nuclei (\( A \) is less than 12), with an increase in \( A \), their \( E_{\text{bond}} \) increases sharply to 6-7 MeV. For example, for the heavy element isotope uranium-238, it reaches 7.6 MeV. For comparison, we note that the bond energy of valence electrons in atoms is 10 eV, that is, \( 10^6 \) times less than the nuclear energy. It is also worth noting that the mass of a nucleus is always less than the sum of the masses of its constituent nucleons (protons and neutrons), and this difference is called the mass excess \( \Delta m \). This is due to the fact that during the nucleus formation, energy is released (part of the mass is spent on formation of a nuclear bond of elementary particles in a nucleus, characterized by the respective nuclear energy), and during the nucleus decay it must be spent. This effect demonstrates the relationship between the transformations of matter, accompanied by the *phenomenon (law) of conservation of mass-energy* and the transition of one type of matter to another (parts of the matter of elementary particles into energy), and vice versa. Apparently, the same effect, but on a smaller scale, should be observed in chemical transformations of substances of an exo- and endothermic nature, as well as biological ones, etc. However, these are much more difficult to notice due to smaller energy consumption upon the formation of bonds in these types of substance at a different level of material organization. In general, the law of conservation of mass and energy in substances [6] is demonstrated by figure 1.

According to figure 1, in general, the energy of the intra-structural interaction of the elements that make up various substances and matter of the microcosm (that is, the interaction or bonds of the elements or particles that make them up), attributed to the unit of their mass (specific energy), decreases as the latter increases. This can be represented as follows:

\[
E / m = K,
\]

(2)
where $K$ is the proportionality coefficient, which takes into account the regular nature of the inverse dependence of the energy of intra-structural interaction of elements of respective level of matter on the mass of an object that forms this level.

That is, with an increase in the mass of various substances, upon transition (figure 1) from the lowest to the highest levels of substance organization ($I - II - III - IV$), the specific bond energy of its structural elements decreases. And, on the contrary, with an increase in the specific energy of the intra-structural interaction of substances, their mass decreases.

As a result, "matter" today is no longer just a philosophical concept, but a natural science concept characterized by mass and energy [2, 3]. At the same time, matter exists in the form of two extreme basic varieties (forms) - discrete (discontinuous in the form of particles of substances and material bodies) and continuous (energy continuum). In accordance with the modern paradigm of multilevel structural organization of matter, transition from one of its variety to another occurs gradually when the ratio of size-mass and energy characteristics changes [1-3]. This happens due to material unity of nature of various objects of the universe and the presence of fundamental differences in their structure and properties within the framework of the laws of conservation of mass – energy and particle-wave dualism.

Thus, energy is a continuous (field) type of matter or an energy continuum. It exists in the form of open or closed (closed within discrete forms of matter) fields.

| $10^4$ | $10^{-3}$ | $8*10^{-7}$ | $4*10^{-7}$ | $10^{-8}$ | $10^{-11}$ | $10^{-13}$ m |
|--------|----------|-------------|-------------|----------|------------|-------------|
| RW     | IR       | Visible spectrum | UV        | X-R      | $\gamma$  | X-Rays      |
| Radio waves | Optical band |               | X-Rays    | Gamma rays |

Figure 2. Electromagnetic wave scale.
The most important distinguishing feature of the continuous forms of existence of the material energy continuum in the form of fields is possessing by the latter the wave characteristics, which vary in a fairly wide range. See, for example (figure 2), the scale of electromagnetic waves [5], while understanding that the wave characteristics of gravitational, nuclear, chemical and other fields would differ from the above electromagnetic ones.

As a result, the material energy continuum has a set of unique properties, among which two most important ones can be distinguished. The first property is the ability to determine the level of interaction between discrete forms of matter (substances and material bodies), up to the formation of stable bonds and the transformation of substances into larger and larger material formations. For example, elementary particles (substances) are transformed into substances with a higher mass - atoms (nuclear physical bonds), then atoms are bound into substances with an even higher mass – chemical substances (chemical bonds), then biological substances, material bodies, in the form of planets in star systems (gravitational bonds). The second property is the ability to determine the shape of the movement of material objects. For example, gravity, together with mass, determines the forms of motion of matter, primarily material bodies (planets, rockfalls, the direction of movement of rivers, etc.), that is, the mechanical forms of motion of matter. Further, it is necessary to distinguish the forms of motion of matter at the level of different substances. As a result, the material energy continuum has a set of unique properties, among which two most important ones can be distinguished. The first property is the ability to determine the level of interaction between discrete forms of matter (substances and material bodies), up to the formation of stable bonds and the transformation of substances into larger material formations. For example, elementary particles (substances) are transformed into substances with a higher mass – atoms (nuclear physical bonds), then atoms are bound into substances with an even higher mass – chemical substances (chemical bonds), then biological substances, material bodies in the form of planets in star systems (gravitational bonds). The second property is the ability to determine the form of material objects' movement. For example, gravity, together with mass, determines the forms of motion of matter, primarily material bodies (planets, rockfalls, the direction of movement of rivers, etc.), that is, the mechanical forms of motion of matter. Further, it is necessary to distinguish the forms of motion of matter at the level of different substances. The chemical bond (chemical energy continuum) in substances and its energy determines the features of the chemical form of motion of substantial matter in the form of chemical transformations. We would like to note the specifics of electric energy as a kind of chemical energy, since it is determined by the presence in the substance of a metallic type of chemical bond in the form of an "electron gas" - delocalized collectivized electrons in the internuclear space. Nuclear bonds in atoms (physical substances) and their energy determine the features of the physical form of motion of matter in the form of physical nuclear transformations. Thermal energy is an apparently mixed physicochemical type of motion of matter. This is due both to the movement of individual molecules relative to each other with the overcoming of intermolecular van der Waals or hydrogen bonds (for example, H2O molecules in water), and to the change in the type of chemical bond upon heating due to the elements in the crystal lattice of a materials vibrating. A special case is the so-called kinetic energy (energy of motion), which, in fact, is no longer energy as such. It characterizes the wave properties in accordance with the de Broglie relation and the Einstein formula (1) for various forms of motion of matter and the magnitude of the energy characteristics depending on mass and speed of material objects’ motion.

Since chemical energy is the main source of heat and electricity, the authors propose a new scientific foundation for the systematization and quantitative assessment of the energy characteristics of chemical compounds of elements (chemicals). It is based on a comprehensive assessment of the contribution of the composition of chemical compounds and their chemical bond type, based on a single model of chemical bond and the "System of chemical bonds and compounds" (SCBC) in the form of a "Chemical Triangle" (CT) [6-13].

The authors of the present paper placed in the triangle's vertices three extreme types of chemical bond (figure 3), while mixed homo- and heteronuclear bonds and compounds formed by these bonds
are located on the left side (homonuclear bonds) and area (heteronuclear bonds) of this CT. Values of covalent character (CC) for some homo- and heteronuclear bonds are given in brackets on the left and right sides of the CT (or, more precisely, on the axes parallel to the sides of CT). The left side of the CT represents homonuclear bonds of s-, p-, d- and f-elements (I), as well as respective basic metallic and nonmetallic (low-, oligo-, highmolecular compounds and polymer solids, like diamond) substances. Heteronuclear chemical bonds are characterized by three components and therefore occupy the area of the CT (e.g., Mg$_2$Sb$_2$, Fig. 3). However, for convenient presentation of various binary heteronuclear chemical compounds (like oxides, nitrides, carbides, etc.) within the CT they are located on additional dotted axes parallel to the right side of the CT (figure 3). Chemical bonds cannot be found at the bottom and right sides of the CT, as well as at M and I vertices (this is why these sides are shown as dotted lines) due to the fact that CC cannot be equal 0.

**Figure 3.** Chemical Triangle is a system of chemical bonds and compounds (SCBC) that combine homo- and heteronuclear binary chemical compounds in the form of nonmolecular metallic, ionic, mono-, oligo-, and macromolecular compounds, along with polymer bodies where ChCDs are discrete chemical compounds (molecular) and ChCCs are continuous chemical compounds (nonmolecular); CC – covalent character of chemical bond, $C_M$ – metallic character, $C_I$ – ionic character.

In the same direction work is underway in the United States and Europe, but there are no attempts to quantify the metallic character, to develop a single model of chemical bonding [14-20] aiming at the creation of a truly chemical system in the form of a Chemical triangle [12, 13]. As a result, the use of this basic scientific innovation for the first time made a symbiosis of the approach of two outstanding Russian chemists: D. I. Mendeleev’s periodic system of atoms (composition – property) and A. M. Butlerov’s theory of chemical structure of matter (composition – chemical structure – property). As a result, this led the authors to create (Figure 3) a truly chemical system – the System of chemical bonds and compounds (SCBC) and a new paradigm for the systematic study of chemical substances (composition - chemical bond and structure - property) [6-13]. The foundation was laid for the creation of a database on the system digitalization and evaluation of the energy stored in various chemicals (gas, coal, fuel oil, peat, wood, etc.) and the most effective ways to extract it from them [21, 22]. The extreme relationship in terms of the influence of the composition and chemical bond type on the energy characteristics of substances depending on the gradual change in the ratio of the covalent...
and metallic bond components in homonuclear and additionally ionic bond component in heteronuclear compounds of elements was shown. The proposed approach and the SCBC can be used in power engineering, chemical industry, construction, industry of nanomaterials, etc. [7-23].

4. Conclusion
For the first time, it was shown that energy, as well as matter, objectively exists in the form of its various material varieties. Energy is a continuous (field) type of matter - the energy continuum. It exists in the form of open or closed (closed within discrete forms of matter) fields. They differ in structure, including the ability to perform different types of work, to determine the forms of interaction and movement of matter in various material systems (substances, material bodies and megamaterial systems). A new scientific foundation is proposed for the quantitative assessment, systematization and digitalization of the energy characteristics of the entire array of chemical compounds of elements (chemicals), based on the System of chemical bonds of compounds (SCBC) in the form of a "Chemical Triangle".

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