

Intra-atomic binding energy

Calculation according to the Wave Model, Part 2

Carbon

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1. Introduction

The emergence of life on Earth is considered in modern science as a complex process of evolution of carbon compounds. Carbon is the basis of all organic substances. Without exception, all living organisms are largely built from carbon compounds. Carbon is the basis of life.

The unique role of carbon in wildlife is due to its properties, which in aggregate are not possessed by any other element of the periodic system.

The nuclear model that currently dominates physics tries to describe properties of atoms, including carbon atoms, but this description is not adequate, since the nuclear atomic model is based on subjective abstract-mathematical postulates. Nuclear model of atoms does not reflect reality and, therefore, causes reasonable doubts.

Knowledge of the true structure of atoms continues to be the most important problem of physics.

Recently, significant progress has been made in this direction. Based on the dialectical concept, according to which the Universe is a material-ideal system being in a continuous oscillatory-wave motion, a conceptually new theory of the structure of matter, called the Wave Model, was developed, and as a result, unique data were obtained.

It was shown that true atoms are only hydrogen (single-nucleon) atoms, to which we attribute a proton, a neutron and the simplest hydrogen atom - a protium. The remaining atoms of the elements presented in the periodic table, as follows from the solutions of the WM, are molecules of the hydrogen atoms.

These solutions were considered in more detail in a number of author's publications [1], and were presented at international conferences, for example, in 2017 in Brussels and Berlin [2, 3]. Therefore, we will show here only some fragments of these solutions, which are necessary for calculations and completeness of the content of this article.

2. Shell-nodal structure of the carbon atom

Fragments of solutions of the wave equation $\Delta\hat{\Psi} - \frac{1}{c^2} \frac{\partial^2 \hat{\Psi}}{\partial t^2} = 0$, revealing the nodal structure of the carbon atom ${}^{12}_6C$, which in this case is a *six-nodal elementary molecule of the hydrogen atoms*, are shown in Fig. 1.

The carbon atom has five *empty potential-kinetic polar nodes* (at $m = 0$; $l = 0, 1, 2$) located along the z-axis, one toroidal *ring*, six *potential polar-azimuth nodes* located in two wave shells ($m = \pm 1$; $l = 1, 2$) completed with coupled hydrogen atoms, and (not shown here) six empty *kinetic polar-azimuth nodes* lying on radial kinetic shells in a perpendicular plane relative to the plane of the disposition of potential nodes.

We see that the carbon atom-molecule has a two-fold symmetry. The latter peculiarity should affect the structure of the corresponding compounds.

Specific properties of carbon compounds in more extent depend on the polar nodes. For example, empty polar nodes of the constituent carbon atoms-molecules *must form* in a plane of two-dimensional hexagonal lattice of graphene when binding (it is easy to show) the parallel empty channels (in a certain crystallographic direction). This means that the two-dimensional hexagonal lattice of graphene is anisotropic and has two-fold symmetry, but not six-fold as in a perfect hexagonal lattice.

As a consequence, the movement of charges along the channels, as it should be expected, should be practically without obstacles. Indeed, this feature, naturally conditioned by the crystallographic anisotropy of the constituent atoms-molecules of carbon, was confirmed by the discovery of the conductivity anisotropy predicted in graphene [4]. Anisotropy of unstrained pristine graphene was also, further, well confirmed by optical methods.

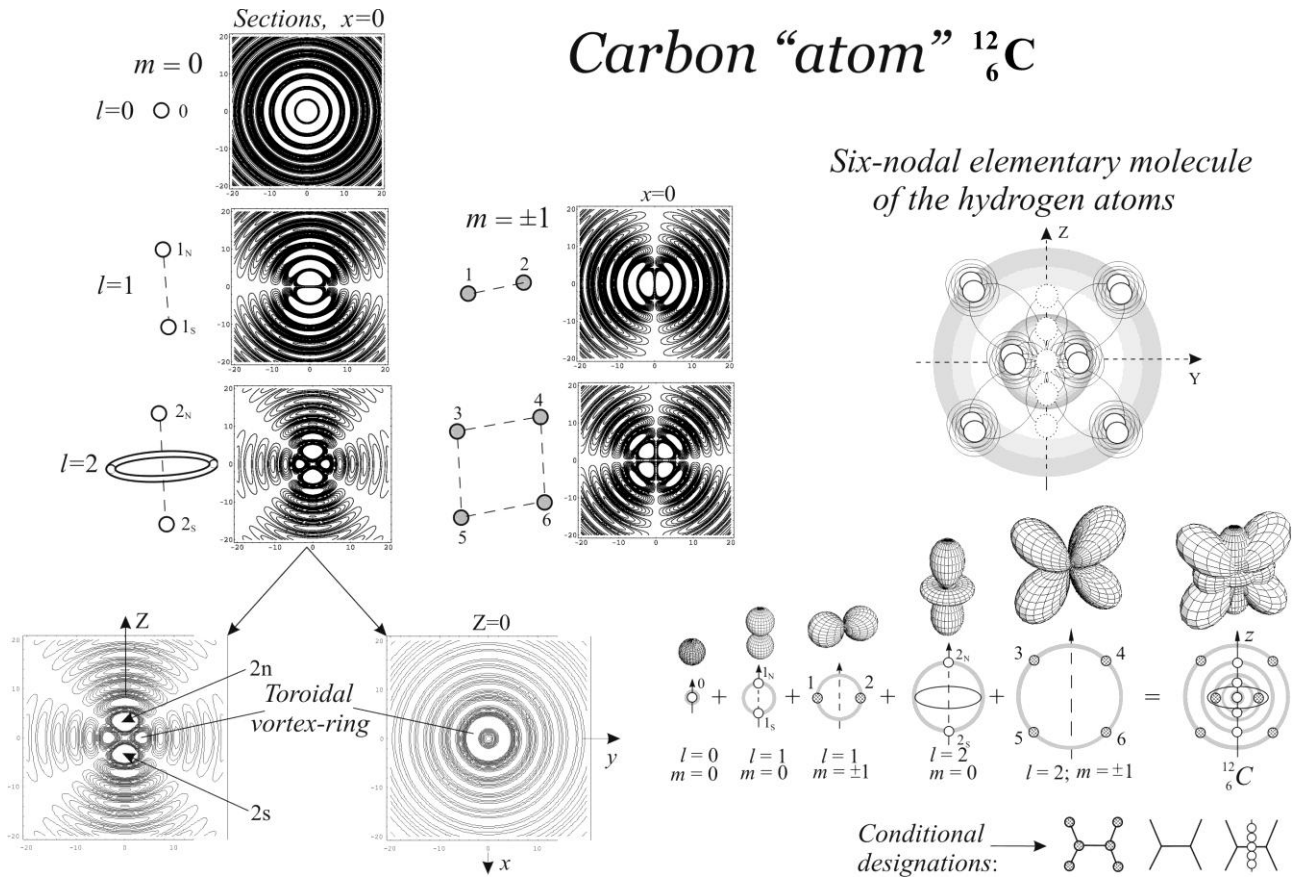


Fig. 1. Potential polar-azimuth functions $\Theta_{l,m}(\theta)\text{Cos}m\varphi$ ($l=0, 1, 2$; $m=0, \pm 1$), their two-dimensional images (sections), and the specific points (designated conditionally by small enumerated circles) on the radial shells $R_l(\rho)$ of the carbon atom, which is a six-nodal elementary molecule of the hydrogen atoms.

The degree of filling of the nodes, external potential *polar-azimuthal* and polar *potential-kinetic* (located along the z -axis), with nucleons (hydrogen atoms, maximum two per node) determines the structure of all carbon isotopes [5, 6], three of which are shown in Fig. 2.

Polar *potential-kinetic* nodes are nodes of *rest* and *movement* at the same time. Therefore, they are places of nonequilibrium states. Consequently, the structures with forcibly (on accelerators) filled polar nodes are extremely unstable. They are characterized by a short period of existence depending on the geometrical configuration (symmetry) of the location of the filled nodes and the degree of their filling (one or two per node).

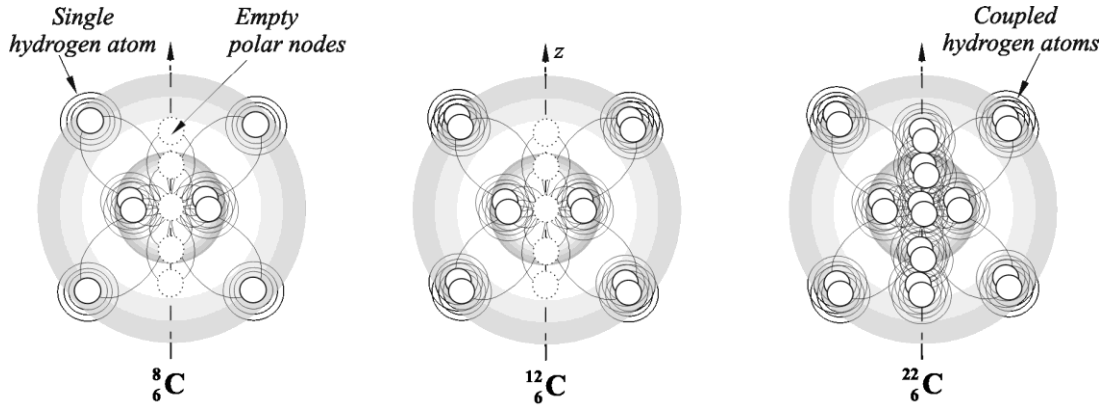


Fig. 2. Nodal structure of three characteristic carbon isotopes: stable $^{12}_6\text{C}$ and two short-lived, the lightest ^8_6C and the heaviest $^{22}_6\text{C}$.

From the nodal structure of carbon, it follows that the heaviest carbon isotope that can be obtained on accelerators is carbon-22.

In Nature hydrogen is mainly in coherent states, in particular, in the form of coupled atoms – hydrogen molecules H_2 . Paired hydrogen atoms, filling polar-azimuth nodes, apparently provide for the stable state of atomic wave shells.

The *condition of pairing* observed in nature is inherent not only in hydrogen atoms in the nodes of individual atoms, but probably also inherent in the compounds of these atoms, at the formation of molecules, liquids, solids.

Therefore, the lightest carbon isotope, carbon-8, with half-filled nodes on the external shell, as shown in Fig. 1, is extremely unstable. Such a structure with only one nucleon per node can appear and exist only for an instant, like its opposite, carbon-22 and other similar nonequilibrium formations. The structure of all possible carbon isotopes is presented in [7].

3. Binding energy of carbon $^{12}_6\text{C}$

The binding energy of nucleons in atoms of the shell-nodal (molecule-like) structure, including carbon-12, is *determined* by the *three* components that we described in Part 1 of this article devoted to the calculation of the binding energy of helium-4 [8]. Therefore, we will not repeat, listing these components here again, but proceed directly to the calculation of the carbon binding energy.

All filled nodes in the carbon atom $^{12}_6\text{C}$ are in the same plane. The strongest internodal bonds are realized between the nearest filled nodes. As you can see, there are five such bonds (Fig. 3). The distance r_1 between the indicated nearest nodes is determined by the root of the Bessel functions [9], $y_{0,1} = 0.89357697$, and is equal to

$$r_1 = y_{0,1} \tilde{\lambda}_e = 1.433196073 \cdot 10^{-8} \text{ cm}, \quad (1)$$

as in the case of a helium atom. Thus, the five internodal bonds responsible for the binding energy in the carbon atom have the same length $r_1 \approx 2.7r_0$ (where r_0 is the Bohr radius),

Please note that the chemical bonds of the interacting carbon atom (six-nodal elementary molecule of the hydrogen atoms) with other atoms-molecules, including the same carbon atoms, at the formation of ordinary compounds, molecules and crystals, according to the WM, are realized along the *four bonds* existed between the *four nodes* (3, 4, 5, 6) of the *external* wave shell of the carbon and the *two nodes* (1 and 2) of its *internal* wave shell (Fig. 3a), accompanied with the overlapping herewith of the nodes belonging to interacting atoms (all details about this can be found in [5]).

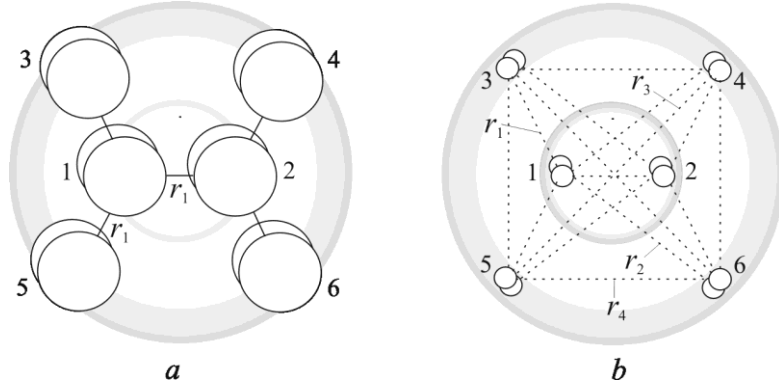


Fig. 3. The position of the five main internodal nucleon (strong, “nuclear”) bonds in the carbon atom ^{12}C (a), and the position of all, including main, characteristic bonds (internodal distances) of interacting nucleon nodes (b) determined by the roots of the Bessel functions.

All other characteristic internodal distances in the carbon atom, shown in Fig. 3b, are also not arbitrary. They are determined, as r_1 , by the roots of Bessel functions. This is justified by regularities of wave processes, described by the Bessel functions that affect the strictly defined spatial structure of material spaces at all levels. So we have:

$$y_{\frac{1}{2},1} = 1.57079633 \quad r_2 = y_{\frac{1}{2},1} \hat{\lambda}_e = 2.519379088 \cdot 10^{-8} \text{ cm} \quad (2)$$

$$j_{0,1} = 2.40482556 \quad r_3 = j_{0,1} \hat{\lambda}_e = 3.857067342 \cdot 10^{-8} \text{ cm} \quad (3)$$

$$j'_{1,1} = 1.84118378 \quad r_4 = j'_{1,1} \hat{\lambda}_e = 2.953049879 \cdot 10^{-8} \text{ cm} \quad (4)$$

As in the case of the helium atom, *three constituents* of the binding energy of the carbon atom must be taken into account.

The *first component* takes into account the *binding energy* of *paired* nucleons in a node, that is, the *deuteron energy* E_D . As we have shown in Part 1 (equality (6)) [8], this energy is equal to

$$E_D = c^2 \Delta m = 2.54363 \text{ MeV} \quad (5)$$

The *second* component of the binding energy takes into account the bond of a node with the atomic shell where this node is located. According to the equation, derivation of which was presented in Part 1 (equation (16)),

$$E_s = \frac{w_u}{z_{l,s}^2} e_l^2(z_{l,s}), \quad (6)$$

for the *1st* and *2nd* nodes (see Fig. 3) of the *internal* atomic wave shell (shell of helium), at $z_{l,m} = y_{0,1}$, we have obtained (Part 1, equation (20)) the following value,

$$E_{int,shell} = \frac{w_u}{y_{0,1}^2} e_0^2(y_{0,1}) = 3.92109 \text{ MeV} \quad (7)$$

Transitions of nucleons from the *internal* shell to the *external* shell, where four nodes are located, are determined by the formula of energy of transitions (Part 1, equation (18)),

$$\Delta E_s = w_u \left(\frac{e_p^2(z_{p,m})}{z_{p,m}^2} - \frac{e_q^2(z_{q,n})}{z_{q,n}^2} \right) \quad (8)$$

For $z_{p,m} = y_{0,1}$ and $z_{q,n} = y_{\frac{1}{2},1}$, we have $E_{trans} = 2.54363 \text{ MeV}$.

The *binding energy*, according to (6), for every of the four nodes of the *external shell* is

$$E_{ext,shell} = \frac{W_u}{y_{1/2,1}^2} e_{1/2}^2 (y_{1/2,1}) = 1.37745 \text{ MeV} . \quad (9)$$

The *third component* of the binding energy of the carbon atom $^{12}_6\text{C}$, the energy of internodal exchange, is determined by the formula (21) of Part 1,

$$E = \omega_e^2 \frac{m_1 m_2}{8\pi\epsilon_0 r} \quad (10)$$

According to the latter, the elementary binding energy, caused by the exchange interaction between two nodes located at a distance r_1 from each other, is

$$E_{exch} = \omega_e^2 \frac{m_p^2}{8\pi\epsilon_0 r_1} = 16.91883553 \text{ MeV} , \quad (11)$$

as in the case of a helium atom (equation (24) of Part 1).

The exchange energy (11) (quantum of energy of nucleon exchange $q_p = m_p \omega_e$) of node number 1 is spent on three equal bonds with nodes 2, 3, and 5; and node number 2 is spent on three equal bonds with nodes 1, 4, and 6 (Fig. 3a).

Thus, the binding energy per node (1 and 2) of the internal shell is

$$E_{exch,1} = (1/3)E_{exch} = 5.639611843 \text{ MeV} / \text{node} . \quad (12)$$

Each of the nodes 3, 4, as well as 5, 6 is connected with only one node, 1 and 2, respectively. Therefore, the binding energy per node (from 3 to 6) is

$$E_{exch,2} = (1/2)E_{exch} = 8.459417765 \text{ MeV} / \text{node} . \quad (13)$$

Thus, we have the following internodal binding energies between nodes under numbers

$$1-2: \quad E_{exch,1-2} = 2E_{exch,1} = 11.27922369 \text{ MeV} / \text{bond} ; \quad (14)$$

$$3-1, 5-1, 4-2, 6-2: \quad E_{exch,3-1} = E_{exch,1} + E_{exch,2} = 14.09902961 \text{ MeV} / \text{bond} \quad (15)$$

Thus, the total energy of internodal exchanges is

$$E_{int-n,exch} = E_{exch,1-2} + 4E_{exch,3-1} = 67.67534212 \text{ MeV} . \quad (16)$$

The resulting sum of all components ((5), (7), (9), and (16)) of the binding energy of the carbon atom $^{12}_6\text{C}$, calculated for q_p , is

$$E_{C,atom} = 6E_D + 2E_{int,shell} + 4E_{ext,shell} + E_{int-n,exch} = 94.37132212 \text{ MeV} . \quad (17)$$

If for calculations we use the neutron exchange charge, $q_n = m_n \omega_e$, we get 94.48781375 MeV .

Subtracting the energy of four valence electrons $4E_e = 2.022 \text{ MeV}$ from (17), we arrive at the energy of the carbon ion $^{12}_6\text{C}^{-4}$,

$$E_{C,ion} = E_{C,atom} - 4E_e = 92.34932212 \text{ MeV} . \quad (18)$$

Thus, the binding energy of the carbon ion $^{12}_6\text{C}^{-4}$, obtained here based on the Wave Model, practically coincides with the binding energy of the carbon atom *nucleus* $^{12}_6\text{C}$ calculated by the mass defect formula,

$$\Delta E_{^{12}_6\text{C}} = c^2 \Delta m = 92.488 \text{ MeV} . \quad (19)$$

In calculations of the helium and carbon binding energies, the first component of the total energy, the binding energy of deuteron D (2_1H) 2.224 MeV (energy of paired nucleons in a node), was obtained from the well-known formula $E_D = c^2\Delta m$ (5).

The derivation of the binding energy of deuteron E_D based on the WM we will show further in Part 3 of this article. The same solutions of the wave equation resulted in the shell-nodal structure of material spaces will be used herewith.

But in this case, at the calculation, we will deal with the space of the subatomic level, namely, with the internal discrete shell-nodal structure of the nucleon (considered in detail in [10, 11]). Basic constituent units of the nucleon, as we have shown, are g-nucleons of the mass $68,24 m_e$.

The binding energy of deuteron will be determined by binding energies of constituent g-particles belonging to the g-nucleon nodes of two nucleons that bind together.

4. Conclusion

Key discoveries made in the framework of the Wave Model allow directly calculate the binding energies of atoms, shown by the example of helium and carbon in Parts 1 and 2 of this article, as well as deuterium and tritium, which will be considered further in Part 3. Here they are:

1. Nuclear-free shell-nodal (molecule-like) structure of atoms.
2. Finite-infinite dynamic structure of elementary particles.
3. Universal law of the central exchange.
4. Fundamental frequency of the atomic and subatomic levels ω_e .
5. The exchange nature of charges, their relationship with fundamental frequencies.

Subsequent three important discoveries that were made based on the above key ones, as their consequence, are the following:

6. Quasiperiodicity of the structure of external wave shells of molecule-like atoms (periodic table of atoms, in the form of nucleon molecules) [12, 13].
7. The entire set of all possible atomic isotopes and their structure [5- 7].
8. Anisotropy of a two-dimensional hexagonal lattice of unstrained pristine graphene.

All together, resulting discoveries confirm the adequacy of theories of the Wave Model: the Dynamic Model of elementary particles and the Shell-Nodal atomic model, on the basis of which these discoveries were made and it became possible to directly calculate the binding energies.

Thus, we have every reason to assert, without any doubt, that the *nuclear model* of the structure of atoms that dominates currently physics is *wrong*.

These are the very important revelations for modern physics that we came to thanks to the Wave Model over the last hundred years.

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