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Resonant interference exchange interaction

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Abstract. **The exchange interaction is manifested not only between identical particles but also between any identical objects or systems. The exchange interaction is responsible for the pairing of atomic electrons in the orthoboson S=1 with the formation of a Bose-Einstein condensate in a strong magnetic field. Resonant interference exchange interaction occurs between an object and a system that has resonant R-states with this object. The RIEX-interaction explains the possibility of carrying out reactions of cold fusion and reactions of low-energy transmutation of chemical elements. The RIEX-interaction is also realized between systems with excited identical resonant R-states. Since the resonant interaction between objects is, in fact, a RIEX-interaction, it is based on all fundamental interactions.**

Keywords: **exchange interaction, resonant interaction, quantum physics, general physics, atomic physics, nuclear physics, cold fusion, nuclear molecules, transmolecules, low-energy nuclear reactions**

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Contents

1. INTRODUCTION

At present, there are four fundamental interactions known in natural sciences: strong (*F*), electromagnetic (*EM*), weak (*W*) and gravitational (*G*). Shipov G. in his theory of physical vacuum [1] introduced such notion as "inertia field" (*I*). The inertia field is associated with the rotational degrees of freedom of material objects. The energy of such inertia field produces torsion of the space around the material object similar to that when the gravitational mass of the material object generates curvature of space. Thus, the gravitational interaction *G* has been enlarged up to the inertial gravitational interaction *IG*.

In quantum physics, one more interaction, a fifth one, is manifested during an interaction between identical particles. This interaction is called the exchange interaction [2]. The exchange interaction is connected with the indistinguishability of identical particles. The identity principle says: it is impossible to distinguish identical particles experimentally. So,

if two identical particles are replaced, each with the other, like $\psi_a(1)\psi_b(2) \to \psi_a(2)\psi_b(1)$, then the result of interaction between them will not change. The result of interaction or the eigenvalues that comply with it will not change if the wave function of the particles is presented as a superposition of wave functions of two states: the eigenstate $\psi_a(1)\psi_b(2)$ and identical state $\psi_b(1)\psi_a(2)$: $\psi^{\pm}(1,2) = \psi_a(1)\psi_b(2) \pm \psi_a(2)\psi_b(1)$.

In paper [3], the exchange interaction is modernized up to resonant interference exchange interaction. The RIEX interaction is the exchange interaction between any objects, A and B, which have resonant *R*-states belonging to a compound system consisting of the objects A and B. Resonant *R*-states are in a certain approximation identical to the objects A and B.

The nature of resonant interference exchange interaction is associated with the overlapping and interference of the wave functions of identical objects having resonant *R*-states. The exchange interaction makes an additional contribution into the total energy of the interacting particle-states for all of the fundamental interactions: *F, EM, W* and *IG*. This contribution is connected with that the total energy of interaction between the identical objects or objects with the *R*-states contains an exchange interference member which is not equal to zero due to their identity. With this, the greater is the overlapping of the wave functions of the identical objects or objects with *R*-states, the greater is the exchange energy.

In this article, the region where resonant interference exchange interaction takes place is considered using a few examples from atomic and nuclear physics.

2. EXCHANGE INTERACTION

2.1. Helium Atom

Let us consider the wave function of two identical fermions 1 and 2 with the spin $s = 1/2$ [4]. The total wave function of two particles is usually represented as the product of the spin wave function of the particles $\{S(1)S(2)\}$ and the wave function of their spatial motion $[\psi_1^V \psi_2^V]$. The spin wave function of the particle can assume two values: with positive spin projection over the preferential direction S^+ and with negative spin projection over the preferential direction S^-. The spin function of two fermions can be represented as the product of spin functions of separate fermions or a combination of their products. It can be symmetric or antisymmetric. Symmetric spin wave functions describe the triplet state of two fermions with parallel spins ($S = 1$, $m_S = +1, 0, -1$), while antisymmetric spin wave functions describe the singlet state with antiparallel spins ($S = 0$).

The wave function of the spatial motion of two fermions must satisfy the same requirements as the spin function of two fermions. It can be either symmetric $\psi^+(1,2)$ or antisymmetric $\psi^-(1,2)$:

$$\psi^+(1,2) = [\psi_a(1)\psi_b(2) + \psi_a(2)\psi_b(1)], \tag{1a}$$

$$\psi^-(1,2) = [\psi_a(1)\psi_b(2) - \psi_a(2)\psi_b(1)]. \tag{1b}$$

Since the total wave function of two fermions must be an antisymmetric function, only the following combinations can be considered acceptable:

$$[\psi_a(1)\psi_b(2) + \psi_a(2)\psi_b(1)] \times \{S^+(1)S^-(2) - S^+(2)S^-(1)\}, \tag{2}$$

$$[\psi_a(1)\psi_b(2) - \psi_a(2)\psi_b(1)]\{S^+(1)S^+(2)\}, \tag{3a}$$

$$[\psi_a(1)\psi_b(2) - \psi_a(2)\psi_b(1)]\{S^-(1)S^-(2)\}, \tag{3b}$$

$$[\psi_a(1)\psi_b(2) - \psi_a(2)\psi_b(1)] \times \{S^+(1)S^-(2) + S^+(1)S^-(2)\}. \tag{3c}$$

The wave functions of two fermions ψ_a and ψ_b are written without account of interaction between them and satisfy the eigen-functions of the energies E_a and E_b. In this case, the energy of the system is: $E = E_a + E_b$. In calculations, the energy of interacting particles is quite often defined with the help of the perturbation theory. All of the fundamental interactions (*F, EM, W* and *IG*) are always simultaneously in the perturbing potential of the interacting identical particles or other "identical objects". The first

correction to the energy of the system in the perturbation theory is calculated as follows:

$$\Delta E^{(1)} = \frac{\int \psi^*(1,2)[F, EM, W, G]\psi(1,2)dV_1dV_2}{\int \psi^*(1,2)\psi(1,2)dV_1dV_2}, \quad (4)$$

where $\psi(1,2)$ is the corresponding wave functions (2) and (3), $dV_1 = dx_1dy_1dz_1$, $dV_2 = dx_2dy_2dz_2$. The integral in the denominator is normalizing.

Let us consider the interaction between the electrons in a helium atom [4] and between protons in a transhelium molecule. In a helium atom the energy of perturbation between the electrons is defined by the Coulomb interaction potential:

$$V = k \cdot e^2/r_{12}, \quad (5)$$

where r_{12} is the distance between the electrons, $k = 1/4\pi\varepsilon_0 = 8.99 \cdot 10^9$ H·м²/C² ($\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m is the electric constant), $e = 1.6022 \cdot 10^{-19}$ C is the electron charge.

Since the perturbation energy V (5) does not depend on the spin variables, there arise identical multipliers, when averaging over such variables in the numerator and denominator (4), and these multipliers then diminish. As a result, $\psi(1,2)$ corresponds to the parts of wave functions (2 and 3), which depend only on the coordinates. Consequently:

$$\begin{aligned}\psi^*(1,2)\psi(1,2) &= \psi_a^*(1)\psi_b^*(2)\psi_a(1)\psi_b(2) + \\ &+ \psi_a^*(2)\psi_b^*(1)\psi_a(2)\psi_b(1) \pm \\ &\pm[\psi_a^*(1)\psi_b^*(2)\psi_a(2)\psi_b(1) + \psi_a(1)\psi_b(2)\psi_a^*(2)\psi_b^*(1)].\end{aligned} \quad (6)$$

The integrals from the first two members (6) are equal to each other. In the denominator (4), they are equal since the interaction of the electrons is symmetric relative to their coordinates. Now we shall introduce the designations C and A:

$$C = \int |\psi_a(1)|^2 [k \cdot e^2 / r_{12}] |\psi_b(2)|^2 dV_1dV_2. \quad (7)$$

The integral C is responsible for the usual average Coulomb energy of repulsion between the electron clouds. The integral A (8) from the members in the square brackets (6) is the exchange integral arising due to the identity of the electrons. Such energy is called the exchange energy.

$$\begin{aligned}A = \frac{1}{2}\int [\psi_a^*(1)\psi_b^*(2)\psi_a(2)\psi_b(1) + \psi_a(1)\psi_b(2)\psi_a^*(2)\psi_b^*(1)] \times \\ \times [k \cdot e^2 / r_{12}] dV_1dV_2.\end{aligned} \quad (8)$$

Thus, correction to energy (4) can be presented as:

$$\Delta E^{(1)} = C \pm A, \; a \neq b, \quad (9a)$$

$$\Delta E^{(1)} = C \pm A, \; a = b, \quad (9b)$$

C and A have positive values [4]. The positive signs in (9*a,b*) refer to the singlet state when the electron spins are contrary to each other ($S = 0$), and the wave function of their spatial motion is symmetric: the state $E_a + E_b + C + A$ and $2E_a + C + A$ (**Fig. 1**). Thus, such states form the electron levels of parahelium. The ground state of parahelium $2E_a + C + A$, 1^1S_0 has the energy of 79.0 eV, while the first excitation of the parahelium state $E_a + E_b + C + A$, 2^1S_0 amounts to 58.4 eV. The energy $2E_a = 108.8$ eV is the doubled energy of ionization of He^+ ion. In the ground state of parahelium the electrons are in the identical state: $a = b$. Therefore, integrals (7) and (8) are equal to each other: $C = A = 15$ eV.

The minus sign in (9*a*) refers to the triplet state when the electron spins are parallel ($S = 1$, $m_S = -1, 0, +1$), while the wave function of their spatial motion is antisymmetric: the state $E_a + E_b + C - A$ (Fig. 1). The ground state of orthohelium $E_a + E_b + C - A$, 2^3S_1 has an energy of 59.2 eV. In orthohelium the exchange interaction attracts the electrons to each other. Orthohelium also has a unique peculiarity: since the spins and magnetic moments of the electrons μ_e in orthohelium are parallel, the orthohelium produces a strong, directional, inhomogeneous

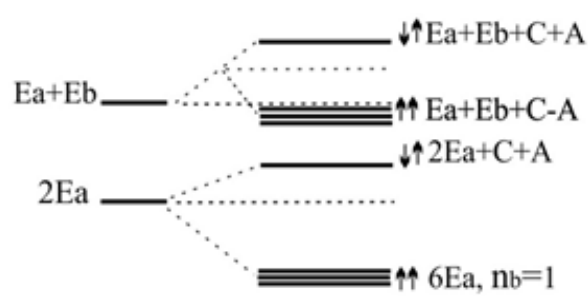

Fig. 1. *Scheme of energy levels of helium atom* [4] *and transhelium under consideration of electron interaction.*

and anisotropic magnetic field. At the centre of the orthohelium, magnetic field right at the nucleus is estimated as being ~ 400 *T*, while it is ~ 70 *T* along its radius $8.76 \cdot 10^{-11}$ m. The magnetic field is calculated according to formula [5]:

$$\mathbf{B}_S = \mu_0 \sum_i \frac{3\mathbf{n}_i(\boldsymbol{\mu}_e \cdot \mathbf{n}_i) - \boldsymbol{\mu}_e}{r_i^3},$$

where $\mu_0 = 1.26 \cdot 10^{-6}$ H/m is the magnetic constant; $\mu_e = 9.29 \cdot 10^{-24}$ $J/T = 5.79 \cdot 10^{-5}$ eV/T; *r* is the distance from the electron to the point where the field $\mathbf{B}_S$ is calculated; **n** is the unit vector in the direction *r*; **i** is the number of electrons having parallel spins.

If there were an antisymmetric coordinate state with $a = b$ and $S = 1$, then $C = A$, and the exchange energy would compensate fully the energy of Coulomb repulsion: $\Delta E^{(1)} = 0$, the minus sign in (9b). In papers [6, 7], the following is considered: the possibility of existence of atoms with paired electrons which form the Bose-Einstein condensate, including the possibility of existence of transhelium.

2.2. Atoms with Paired Electrons - Transatoms

The atoms which have electrons, not necessarily all, in paired state, are called "transatoms". These states arise in a strong magnetic field of more than 30 *T*. In a strong magnetic field, the atoms are inevitably transformed into transatoms! [6] In such a magnetic field the electrons are paired into the orthoboson $S = 1$. The motion of two electrons in orthobosons are rigidly correlated, while the electron spins are parallel to each other, $S = 1$, and both electrons are in one energy state: $a = b$ and $E_a(1) = E_a(2)$.

In paper [6], it is shown that in a strong magnetic field the electrons with parallel spins are paired due to:

- firstly, to the exchange interaction between the electrons, which is of attraction nature; and,
- secondly, due to the arising of electron oscillation around their orbitals (**Fig. 2***a*).

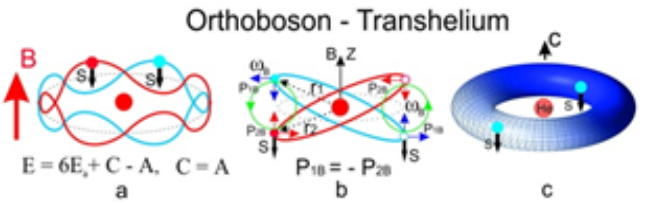

Fig. 2. *a - electron oscillations; b – electron oscillations in the longitudinal and in the transverse magnetic field B directions; c – orthoboson - transhelium.*

Owing to such oscillations of the electron, a new, additional degree of freedom of motion arises [8], which produces a new quantum number, n_b. Then, correlated oscillations arise as a result of the exchange interaction between two electrons. The quantum number of oscillations of the paired electrons are equal to each other by the module; however, they are contrary in their sign: $n_b^1 = -n_b^2$, $n_b = 1, 2, 3\ldots$ Therefore, the Pauli principle is fulfilled for them.

The frequency of oscillations ω_B is connected with the frequency of rotation of the electron at the orbital $\omega_0 = E_0/\hbar$ and the frequency of precession of its orbital moment ω_ℓ by the following ratio [9, 10]: $\omega_B = n_b\sqrt{\omega_o^2 + \omega_\ell^2}$. The energy of oscillation $E_B = \hbar\omega_B$. The oscillations of the electrons are performed both in the longitudinal and transverse direction relative to the propagation of the magnetic field **B** (Fig. 2*b*). Since the electrons in a pair oscillate in the contra-phase $n_b^1 = -n_b^2$, such motion allows two electrons in identical energy states to be found in non-overlapping spatial regions. The trajectories of motion of the electrons can be represented as closed interleaved helices located at the surface of a toroid [7] (Fig. 2*c*). Two electron helices resemble the double helix of a DNA molecule. The trajectories of several orthobosons in a multielectron transatom make an interleaved helical twist. This twist is a toroidal spin electron and magnetic twist, let's call it "torsem twist" or "torsem condensate". So, a quantum paradox arise: "the wave functions of the electrons overlap maximally, and the spatial regions of their motion do not overlap".

Since in the orthoboson and transhelium the wave function of the spatial motion of the

electrons is antisymmetric ($n_b^1 = -n_b^2$,), then $\Delta E^{(1)} = C - A$. Also, because $a = b$, then $C = A$ and $\Delta E^{(1)} = 0$. The exchange Coulomb attraction suppresses the Coulomb repulsion. So, one more quantum paradox arises: "waves extinguish the wind". For $n_b = 1$ the energy of paired electrons in the helium transatom is: $6E_a = 3 \cdot 108.8 = 326.4$ eV or 163.2 eV for each electron [7] (Fig. 1). The radius of transhelium is less by three times in comparison with the state $2E_a = 108.8$ eV: $R_{THe} = 8.83 \cdot 10^{-12}$ *m*.

Two atoms of hydrogen, which interact in a strong magnetic field due to the arising oscillations of the electrons ω_B, join into a transmolecule of hydrogen "H_2" where the electrons are paired into orthoboson [7] (**Fig. 3***a*). Such orthoboson produces in the hydrogen transmolecule "H_2" an electromagnetic potential well with the magnetic induction vector at the centre ~10^4 *T*. In such a ultrastrong and inhomogeneous magnetic field the protons ($S_p = 1/2$) will have parallel spins ↑↑. Like the electrons, the protons in the hydrogen transmolecule form a bound state – the orthoboson $S = 1$ – at the expense of their own exchange interaction and their own correlated oscillations. Similar to the electrons, the exchange Coulomb interaction of the protons in the first order of the perturbation theory fully compensates their Coulomb repulsion. This leads to approaching of the protons to the nuclear distances with the formation of a transmolecule of "helium-pp" ("He-pp") [7] (Fig. 3*b*). The protons in the transmolecule "He-pp" can be replaced by deutrons *d* and tritons *t*. As a result, the transmolecules "He-dd" and "He-tt" are formed. Formation of the transmolecule of hydrogen "H_2" and transmolecule "He-pp" is accompanied by characteristic radiation in the region of deep ultraviolet radiation in the range from 27 eV to 150 eV [7, 11]. Exactly this radiation was registered in the extreme ultraviolet spectroscopy experimental studies of the microwave discharge in the helium-hydrogen plasma [12]. The scheme of electron transitions from the states of atoms and ions of hydrogen, as well as of hydrogen molecules and ions of hydrogen molecules into the hydrogen transmolecules "H_2" and further, into the "He-pp" transmolecule, is presented in **Fig. 4**. The transitions with emission of two photons are depicted by double lines. The figures are given in electron-volts.

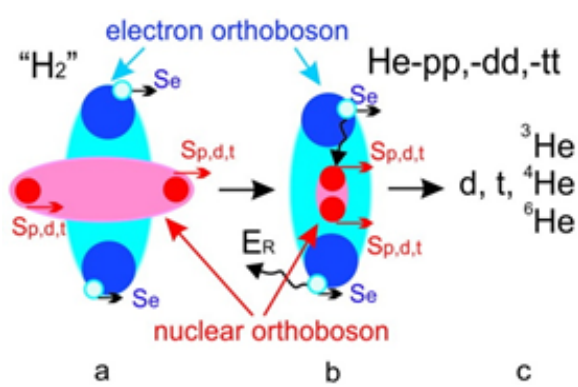

Fig. 3. *Transformation of hydrogen transmolecule into "helium" transmolecule.*

2.3. Transmutation Reactions at Protons

Protons, apart from the electromagnetic interaction *E-M*, enter into a strong interaction: *F*. The potential *F* has a negative value. Therefore, the potentials of strong and Coulomb interactions have opposite signs. So, when the proton spins are parallel, they repel each other at the expense of strong interaction [3]. Due to this, reaction (10) in the He-pp transmolecule will be impossible. But an opportunity will be

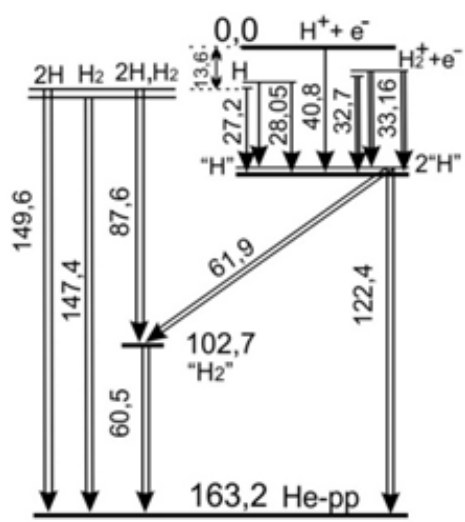

Fig. 4. *Scheme of electron transitions in the "hydrogen-helium" transmolecule in He + H_2 plasma.*

opened for reaction (11) with the participation of the electron orthobosons $2e^-$.

$$p + p \rightarrow d + e^+ + \nu_e + 0.42 \text{ MeV}, \quad (10)$$

$$p + p + 2e^- \rightarrow d + \nu_e + e^- + 1.44 \text{ MeV}. \quad (11)$$

The protons in the He-pp transmolecule have parallel spins. The strong *F*-exchange interaction of protons repel them from each other; the Coulomb *E*-exchange interaction fully compensates the Coulomb repulsion of protons; and the weak *W*-exchange interaction with the participation of electron orthoboson allows reaction (11).

Let us consider the proton-proton, neutron-neutron and neutron-proton interactions. The proton cannot have a bound state with another proton, just like the neutron does not have a bound state with another neutron. The proton cannot be attracted to another proton, just like the neutron, to another neutron. Therefore, at *p-p* and *n-n* interactions at the wavelengths of their wave functions ($\lambda_{p,n} = h/m_{p,n} \cdot \upsilon$) the perturbing strong interaction *F*, which enters into the exchange interaction, will change the antiparallel spins of colliding protons $p\uparrow\downarrow p$ and neutrons $n\uparrow\downarrow n$ into the parallel $p\uparrow\uparrow p$ and $n\uparrow\uparrow n$. Then the spatial wave function of protons or neutrons becomes antisymmetric and the protons or neutrons repel each other because the exchange strong *F* repulsion surpasses the exchange Coulomb attraction [3]. Due to this, reactions at the expense of strong interaction using free, and even more so, thermonuclear protons (10) or neutrons (12), are impossible:

$$n + n \rightarrow d + e^- + \ + 3.04 \text{ MeV}. \quad (12)$$

Reactions (10) and (12) at protons and neutrons being in the electromagnetic or nuclear potential well with antiparallel spins are also impossible due to the necessity to fulfill the angular momentum conservation law. The spins of particles e^+ and $\tilde{\nu}_e$ are directed along the momentum direction (they have a right-hand helicity), whereas the spins of particles e^- and ν_e are directed against the momentum (they have a left-hand helicity). Probably, this is why the chief thermonuclear reaction (10) was not fulfilled on the Earth in laboratory conditions. It cannot pass at the Sun and in stars. Consequently, the stars are not thermonuclear reactors in the channels of reaction (10). In the strong magnetic fields of the stars, the He-pp transmolecules are formed, and in channel (11) low-energy transmutation reactions with participation of electron orthobosons $2e^-$ take place.

The reaction $p + p + 2e^- \rightarrow d + \nu_e + e^- + 1.44$ MeV (11) differs from the reaction with capture of one electron: $p + p + e^- \rightarrow d + \nu_e + 1.44$ MeV (**pep**) where emission of a monoenergetic neutrino takes place. In reactions (11), the neutrino spectrum is continuous. However, it must differ from the neutrino spectrum at beta decay since it occurs with two paired electrons of energy 326 eV. The contribution of reaction (11) was not taken into account when comparing the experimental energy spectrum of solar neutrinos [13], obtained at the Borexino set-up, with the summary theoretical neutrino spectrum produced in a number of nuclear reactions. As a result of comparison, reaction (10) passes with the probability 99%, and the (pep) reaction with the probability 0.24%. Therefore, it is necessary to carry out processing of the experimental neutrino spectrum using reaction (11).

With the production of deuterium and trithium, He-dd and He-tt transmolecules will be formed, which are also nuclear orthobosons. They enter into non-Coulomb nuclear reactions of transmutation, including with the participation of electron orthobosons, with the formation of protons, neutrons, deuterons, tritons, such nuclei as ^{3}He, ^{4}He, ^{6}He → ^{6}Li (Fig. 3*c*) [6]:

$d + d \rightarrow t + p + 4.03$ MeV,

$d + d \rightarrow {}^3He + n + 3.26$ MeV,

$t + t \rightarrow {}^4He + 2n + 11.3$ MeV,

$d + d + 2e^- \rightarrow 4He + 2e^- + 23.85$ MeV,

$t + t + 2e^- \rightarrow 2e^- + 12.3$ MeV + ^{6}He (β^-, $T_{1/2}$ = 0.8*c*) → $^6Li + e^- + \tilde{\nu}_e + 3.5$ MeV.

Further on, the atoms of orthohelium of ^{4}He with their own strong magnetic fields (~70 *T*) become unified and produce multi-nuclear transmolecules, where multinuclear reactions

with synthesis of heavier chemical elements with the nucleus charge $Z > 6$ take place [14]. Thus, the reactions of low-energy transmutation ensure the star and planetary nucleosynthesis [6, 15, 16]. We shall note that only with the appearance of deuterium at the Sun and in the stars thermonuclear reactions become possible. Therefore, the Sun and stars are reactors of mixed type: transmutational and thermonuclear ones.

Due to the isotopic invariance of the strong interaction, the protons can interact with the neutrons in resonance. The neutron and proton have a bound state, that is the deuteron. The proton captures a thermal neutron with the cross section $\sigma_T = 0.332$ barn. Such a small cross section of capture, σ_T, is due to that the deuteron has an only bound state being in the nuclear potential well, and it does not have any states close to and higher than the binding energy of the deuteron: $E_d = 2.224$ MeV. As a result, the interaction between the proton and neutron produces a deuteron with the spin $S = 1$. In the deuteron, the spins of the neutron and proton are parallel, and their spatial wave functions are symmetric. With that, their total wave function is antisymmetric due to the antisymmetric isotopic spin component of their wave function: *n, p*. As a consequence, the neutron and the proton will be attracted to each other because the spatial component of their total wave function is symmetric; however, with this the spin component of their wave function is also symmetric, that is their spins are parallel: $p\uparrow\uparrow n$. The ~65% possibility for the proton and neutron to reside outside of the nuclear potential well of the deuteron can be interpreted as the existing resonant interference exchange interaction between the proton and the neutron (chapter 3).

- In the atom which is in a strong magnetic field, the exchange Coulomb interaction allows the atomic electrons to be paired into the orthobosons with $S = 1$. Thus, a transatom is formed which has a spin electronic Bose-Einstein condensate. The spins and spin magnetic moments of all the orthobosons of a transatom are oriented in one direction. The spin electronic condensate or torsem condensate produces inside and around the transatom an ultrastrong, directional, inhomogeneous and anisotropic magnetic field.
- The exchange Coulomb attraction between any two identical charged fermions that make up the orthoboson in the first order of the perturbation theory fully compensates the Coulomb repulsion between them.
- The strong exchange interaction between colliding protons and neutrons prohibits them to enter into nuclear and thermonuclear reactions with the formation of the deuteron.

3. RESONANT EXCHANGE INTERACTIONS

3.1. Radiative Neutron Capture

In paper [3], the resonant interference exchange interaction was introduced. The RIEX-interaction is an exchange interaction between any objects, *A* and *B*, which have resonant *R*-states belonging to a compound system composed of objects *A* and *B*. The resonant *R*-states, in some approximation, are identical to the objects *A* and *B*. The *R*-states become real when they are excited at the wavelengths of the wave functions of the *A* and *B* objects. Therefore, the spatial region of the exchange interaction for all fundamental potentials: *F, EM, W* and *IG*, is defined by the wavelengths of the wave functions of resonantly interacting identical objects *A* and *B*. When the wave functions of the objects *A* and *B* are overlapped, then they appear simultaneously in two states: in the eigenstate $\psi_a(A)\psi_b(B)$ and in the identical state $\psi_b(A)\psi_a(B)$. Their full wave function is $\psi^{\pm}(A,B) = \psi_a(A)\psi_b(B) \pm \psi_b(A)\psi_a(B)$. The eigen-part $\psi_a(A)$ at its eigen-spot $\underline{a}$ interacts with the identical part $\psi_a(B)$, while the eigen-part $\psi_b(B)$ at its eigen-spot $\underline{b}$ interacts with $\psi_b(A)$. Thus, thanks to the resonant interference exchange

interaction, the short-range strong F and locally weak W interactions become long-range ones.

In paper [3], RIEX-interaction of neutrons, protons and deuterons with atomic nuclei is considered. If the compound nucleus consisting of a nucleus target and neutron n, or proton p, or deuteron d, has resonance R-levels, then n or p, or d upon entering into resonance with one of such R-levels start to interact with it through exchange interaction. The resonant R-state is excited at the wavelength of eigen wave functions $\psi_n(n)$ or $\psi_p(p)$ or $\psi_d(d)$. The R-state possesses its eigen wave function $\psi_R(R)$. Due to the exchange interaction the R-state as well as the neutron, the proton, the deuteron in addition to the eigenstates, they have identical states: $\psi_n(R)$, $\psi_p(R)$, $\psi_d(R)$, $\psi_R(n)$, $\psi_R(p)$, $\psi_R(d)$. The full antisymmetric wave function of the R-level and neutron n is:

$$[\psi_n(n)\psi_R(R)-\psi_n(R)\psi_R(n)]\cdot\{S^+(n)S^+(R)\}; \quad (13a)$$

$$[\psi_n(n)\psi_R(R)-\psi_n(R)\psi_R(n)]\cdot\{S^-(n)S^-(R)\}; \quad (13b)$$

$$[\psi_n(n)\psi_R(R)-\psi_n(R)\psi_R(n)]\times \times\{S^+(n)S^-(R)+S^-(n)S^+(R)\}; \quad (13c)$$

$$[\psi_n(n)\psi_R(R)+\psi_n(R)\psi_R(n)]\times \times\{S^+(n)S^-(R)-S^-(n)S^+(R)\}. \quad (13d)$$

For the proton, the symbol n in (13) should be replaced with "p". For the deutron-boson (S = 1), the full wave function $\psi(d,R)$ should be symmetric.

The potential making a key contribution into the exchange energy is the strong interaction F:

$$\Delta E_{nR}^{(1)}=\frac{\int\psi^*(n,R)[F]\psi(n,R)dV_ndV_R}{\int\psi^*(n,R)\psi(n,R)dV_ndV_R}. \quad (14)$$

The energy of strong perturbation, F, depends on the spin variables. However, we assume that the perturbation F does not change the R-state and the spin orientation of the neutron (or proton). Therefore, when averaging spin wave functions in the numerator and in the denominator (14), identical multipliers appear which diminish. As a result, $\psi(n,R)$ corresponds to the parts of wave functions (13) which depend only on the coordinates $\psi(n,R)=[\psi_n^V\psi_R^V]$. Then:

$$[\psi_n^V\psi_R^V]^*\cdot[\psi_n^V\psi_R^V]=\psi_n^*(n)\psi_R^*(R)\psi_n(n)\psi_R(R)+ +\psi_n^*(R)\psi_R^*(n)\psi_n(R)\psi_R(n)\pm \pm[\psi_n^*(n)\psi_R^*(R)\psi_n(R)\psi_R(n)+ +\psi_n^*(R)\psi_R^*(n)\psi_n(n)\psi_R(R)]. \quad (15)$$

The integral from the functions represented in the squared brackets is the exchange integral. The plus sign (15) responds to the symmetric coordinate wave function in (13d); and the minus sign, to the asymmetric one in (13a,b,c).

The integrals from the first two members in (15) characterize a strong interaction, F, at the distance exceeding its action between the R-state and the neutron (or proton), as well as between part of the neutron in the R-state and part of the R-state in the neutron. Thus, these integrals are equal to zero:

$$\int|\psi_n(n)|^2F|\psi_R(R)|^2dV_ndV_R=0,$$

$$\int|\psi_n(R)|^2F|\psi_R(n)|^2dV_ndV_R=0.$$

So, one can consider that in numerator (9) for the strong interaction:

$$[\psi_n^V\psi_R^V]^*\cdot[\psi_n^V\psi_R^V]= =\pm[\psi_n^*(n)\psi_R^*(R)\psi_n(R)\psi_R(n)+ +\psi_n^*(R)\psi_R^*(n)\psi_n(n)\psi_R(R)]. \quad (16)$$

The potential F has a negative value. The exchange integral in this case also has a negative value. So, the nucleus with the R-state and the neutron (or proton) are attracted to each other when their spatial wave function is symmetric, while their spins are antiparallel. The deuteron-boson is attracted to the nucleus with the R-state when both the spatial and the spin components of the total wave function are symmetric or antisymmetric.

The R-state of the compound nucleus is excited by the neutron (p or d) proportionally to the coefficient K: $\psi_R(R)=K\psi_n(n)$ or $\psi_R(r)=K\psi_n(r)$. The coefficient K characterizes the affinity of the neutron (p or d) with the R-state. Usually $K<1$ or $K<<1$. For each R-state the coefficient K is individual, and correspondingly,

the sum of interactions of the neutrons (*p* or *d*) together with all of the *R*-states of the compound nucleus is individual for the specific isotope. The identical state of the neutron in the *R*-state equals to its eigen *R*-state: $\psi_R(n) = \psi_R(R)$. The overlapping in the wave functions of the neutron $\psi_n(n)$ and the *R*-state in the neutron $\psi_n(R)$ will increase: $\psi_n(n)\psi_n(R) = K^2|\psi_n(r)|^2$, proportionally to the neutron density $|\psi_n(r)|^2$ at the distance *r* from the nucleus. With the same coefficient the overlapping in the wave functions of the *R*-state and the neutron in the *R*-state will grow: $\psi_R(n)\psi_R(R) = K^2|\psi_n(r)|^2$. Eventually, the integral from (16) and the energy of the exchange interaction $\Delta E^{(1)}(r)$ (14) are written as follows:

$$\Delta E_{nR}^{(1)}(r) \sim 2K^4 \int |\psi_n(r)|^2 F |\psi_n(r)|^2 d^2V_n. \quad (17)$$

Since the potential of the strong interaction, *F*, has a short range and the property of saturation, integral (17) has its value only in the volume which is commensurable with the nucleus volume V_A, the diameter of which is equal *ØA*. Therefore, we will consider the value of action of *F* at the exchange interaction of the neutron (*p* or *d*) with the *R*-state over the entire length *L*, from the place where this interaction starts up to the nucleus, as constant: $F_R = const$. That is, F_R does not depend on the distance *r* between the neutron and the nucleus over the entire length L. The length L correlates with the wavelength of the neutron (*p* or *d*) as $L \sim K^4 \cdot \lambda_{n,p,d}$. Since $\lambda_{n,p,d}$ or the wavelength of the wave function of the neutron (*p* or *d*) is much greater than the dimensions of the nucleus $\psi_n(r) >> ØA$, then $\psi_n(r) = const$ in the volume V_A. Consequently, from (17) the energy of the exchange interaction $\Delta E^{(1)}(r)$ is proportional to the squared neutron (*p* or *d*) density in the nucleus region V_A, when the neutron is at the distance *r* from the nucleus.

$$\Delta E_{nR}^{(A)}(r) \sim 2F_R \cdot K^4 |\psi_n(r)|^4 \int_{V_A} d^2V_n. \quad (18)$$

The integral in (18) is the squared volume of the nucleus, V_A^2. It is proportional to the squared mass number of the nucleus: $V_A^2 = \rho M^2$.

$$\Delta E_{nR}^{(A)}(r) \sim 2F_R \cdot K^4 |\psi_n(r)|^4 \cdot V_A^2. \quad (19)$$

Let us introduce the designation *U*, which includes $2F_R$, ρ and normalizing integral (9):

$$\Delta E_{nR}^{(A)}(r) = UK^4M^2 \cdot |\psi_n(r)|^4. \quad (20)$$

The value *U*, which characterizes the potential of a strong interaction between a neutron or a proton with the *R*-state, is estimated as follows: U = 9-12 MeV [3].

During the interaction between the neutron (*p* or *d*) with the *R*-state, its wave function is transformed from the plane wave into the wave function of the bound state. The orbital moment of the thermal neutron (*p* or *d*) interacting with the nucleus: $\ell = 0$. So, we will represent the wave function $\psi_n(r)$ [or $\psi_p(r)$, or $\psi_d(r)$] as the radial part of the *S*-wave function of the electron which was on the orbital with the radius a_0 and rotates around the nucleus with the quantum numbers $n = 1$ and $\ell = 0$. The density distribution of such an electron in the radial direction is characterized by the function: $P(r) = C\left[r^2 \exp\left(-\frac{2r}{a_0}\right)\right]$, where *C* is the normalizing constant, a_0 is the radius of the electron orbital [4]. **Fig. 5** provides in relative units: the red line which corresponds to the values of the function from the nucleus up to a_0 (500 fm); the green line shows the neutron (*p* or *d*) density in the nucleus, when neutron resides at the distance *r* from the nucleus: $|\psi_n(r)|^2 = P(L - r)$; and the blue line indicates the potential of

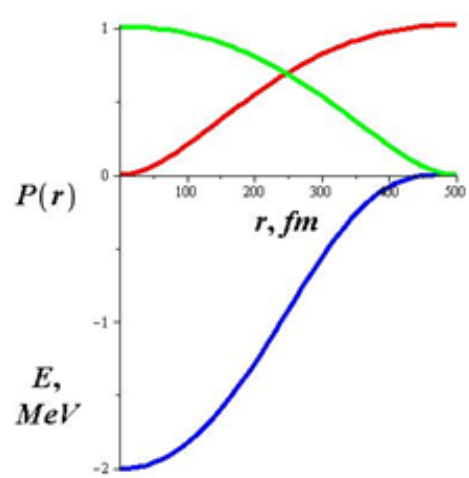

Fig. 5. *The red line is the radial density of the orbital electron; green – neutron density in the nucleus located at a distance r from a neutron; blue – RIEX potential.*

the exchange interaction $\Delta E_{nR}^{(1)}(r) = -[P(L-r)]^2$ (the values $a_0 = L = 500$ fm and $UK^4M^2 = -2$ MeV are chosen arbitrarily).

Thus, during the interaction of a neutron with the *R*-state of the compound nucleus at the distance $L \sim K^4 \lambda_n$ up to the nucleus there is a potential pit of depth equal to UK^4M^2. In **Fig. 6**, the red line shows the nuclear potential of nickel, for example, ^{64}Ni; the blue line indicates the potential of the RIEX-interaction; and the green line corresponds to the total potential (the value $UK^4M^2 = -2$ MeV is chosen arbitrarily).

Upon coming into the potential pit, the neutron finds itself in the region which is lower than the binding energy of the neutron, where the density of neutron energy levels is considerable and, therefore, the resonant interaction of the neutron with them is also great. Thus, thanks to the resonant interference exchange interaction the neutron is captured by the nucleus at the distance *L*.

3.2. Cold Fusion

In contrast to the neutron, both the proton and the deuteron have electric charge, therefore when they approach the nucleus they experience a Coulomb barrier. However, behind the Coulomb barrier of a compound nucleus, the proton, apparently, as well as the deuteron, has a large quantity of resonance levels up to the Coulomb barrier height (**Fig. 7**). The energy of the proton and deuteron can range from the thermal one up to the energy equal to the Coulomb barrier height. Therefore, when losing its energy on the way of approaching the nucleus, the proton

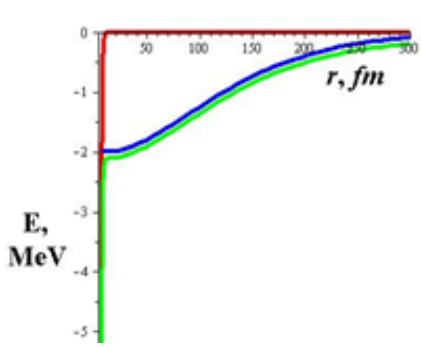

Fig. 6. *Red line - nuclear potential Ni; blue – RIEX potential Ni-n; green - total potential Ni+n.*

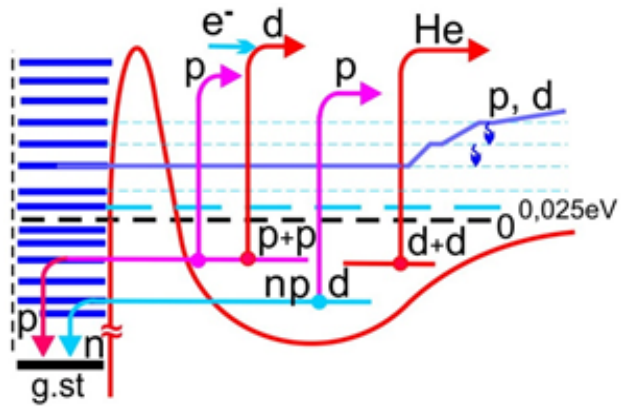

Fig. 7. *The levels of the compound nucleus A + p (d) beyond the Coulomb barrier and the interaction with them of a proton or deuteron.*

or deuteron "scan" the energy levels of the nucleus behind the Coulomb barrier, up to the moment when they enter into resonance with the suitable *R*-level (Fig. 7). The suitable *R*-level is defined by the requirement of supremacy of its exchange energy with the proton over the energy of Coulomb repulsion of the proton off the nucleus. The suitable *R*-levels may exist above the "room" energy 0.025 eV. In such a case, the RIEX interaction requires energy stimulation. Such stimulation can be supplied by heating the "working body" or by affecting it using external sources of supplementary energy (laser, microwave radiation, etc.). Thus, during an interaction of the proton or a deuteron with the *R*-state at the length $L \sim K^4 \lambda_{p,d}$ from the nucleus, there arises formation of a potential well. The potential well depth and the distance from the well bottom to the nucleus are defined by the difference between the attracting energy of the exchange interaction $-UK^4M^2|\psi_p(r)|^4$ and the energy of the Coulomb repulsion $V = k \cdot Ze^2/r$, where *Z* is the nucleus charge. In **Fig. 8**, the red line refers to the nuclear potential of Ni (nickel) plus the Coulomb potential Ni+p, and the blue line corresponds to the RIEX potential (values 400 F_m and $UK^4M^2 = -2$ MeV are chosen arbitrary), and the green line indicates the summed potential.

As a result, an "exchange" potential well is formed at the Coulomb barrier of the nucleus A. A nuclear molecule is created as follows: A+p

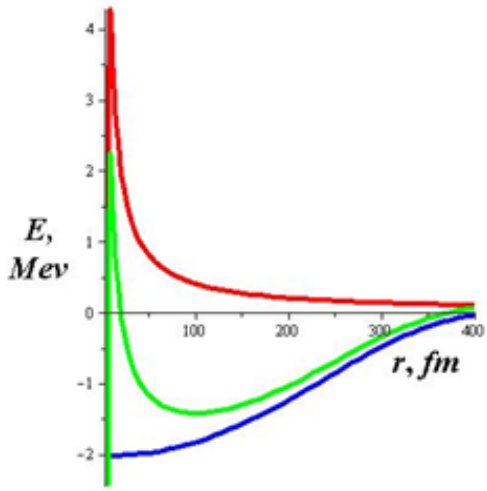

Fig. 8. *Red line - nuclear plus Coulomb potentials Ni+p; blue − RIEX potential Ni-p; green - total potential Ni+p.*

and A+d. At a large concentration of protons (deuterons) for one nucleus of the main element, a second proton and a second deuteron may fall into the exchange well: A+p+p and A+d+d. The proton-fermions in the well will have antiparallel spins in the ground state. The deuteron-bosons may have differently oriented spins as the deuteron levels are closely-spaced triplet states (S_d = 1, m_S =+1, 0, -1). This opens a possibility for the reactions of cold fusion (Fig. 7):

$$d + d + A \rightarrow {}^4He + A + 23.8MeV, \quad (21)$$

$$p + p + A \rightarrow d + e + \nu_e + A + 0.42MeV. \quad (22)$$

As was explained in 2.3, the protons with antiparallel spins cannot perform reaction (22). Therefore, this gives a possibility for the reaction with the capture of the orbital *K*-electron:

$$p + p + e^- + A \rightarrow d + \nu_e + A + 1.44\ \text{МэВ}. \quad (23)$$

When two protons are in the exchange well, there arises a possibility for tunneling of one of the protons through the Coulomb barrier right into the ground state of the compound nucleus without gamma emission (Fig. 7).

$$p + p + {}_zA \rightarrow {}_{z+1}B + p + Q. \quad (24)$$

This reaction will compete with reaction (17).

We shall note that the deuteron which resides in the exchange well of the nuclear molecule is polarized by the Coulomb field of the nucleus: the neutron is placed closer to the nucleus than the proton. Therefore, the neutron may perform radiationless transition into the ground state of the nucleus A with proton emission (Fig. 7). The proton energy, with accuracy up to the nucleus recoil energy, will be equal to the neutron bounding energy in the nucleus ~8 MeV minus double energy of the level (neutron energy plus proton energy), occupied by the deuteron in the exchange potential well q_d and minus deuteron binding energy 2.224 MeV:

$$d + {}_Z^N A \rightarrow {}_Z^{N+1} A + p + (8 - 2q_d - 2.224) \quad (25)$$

where *N* is the number of neutrons in the nucleus. The level occupied by the deuteron in the potential well q_d, can be nominally assumed as its depth. This reaction is possible also because the proton and neutron are above the nuclear potential well of the deuteron with the probability ~65%. Reaction (19) is even more so probable if the neutron has a resonance level behind the Coulomb barrier of the compound nucleus. Thus, at dissolving of deuterium in a thin layer or powder of titanium or palladium, one can register protons with the energy defined by the depth of the potential well q_d.

The proton and neutron in a deuteron exist 65% of their time in the quasi-free state. So, they interact independently with their *R*-states. It follows from this that the reactions of cold fusion on deuterons must have notable cross sections for the isotopes, for which the cross sections of radiative capture of neutrons are substantial as well.

Besides that, due to the isotopic invariance of strong interaction, the proton can interact resonantly with the neutron *R*-levels both, as being behind the Coulomb barrier, and belonging to the isotopes with substantial resonant absorption of neutrons [17]. In this case, the proton is attracted to the nucleus which has resonant neutron *R*-levels, when their spins are parallel.

3.3. Nuclear Molecules

As a result of RIEX-interaction between the proton or deuteron with the atomic nucleus ${}_Z$A, a nuclear potential well is formed at the Coulomb barrier of the nucleus. Due to this nuclear molecules are created as follows: ${}_Z$A+p

and $_{Z}$A+d. The lifetime of the corresponding molecule is defined by the transparency of the Coulomb barrier. Also, in spite of the decrease in the height and width of the Coulomb barrier, the nuclear molecules $_{Z}$A+p and A+d which have been formed may be stable (A+d is stable with an accuracy up to the reaction of neutron capture; see 3.2). Implicitly, it is confirmed by the absence of gamma radiation when dissolving hydrogen or deuterium in titanium, nickel or palladium. The mass of a nuclear molecule $_{Z}$A+p differs from the atom mass of $_{Z+1}$B by the difference between the proton binding energy Q_p in the $_{Z+1}$B nucleus and the depth of the potential well q_p of the nuclear molecule. Depending on $_{Z+1}$B, the difference $Q_p - q_p$ or the nuclear-molecule mass defect can amount to several MeV. The difference in the mass of a few tens of keV can be at present determined using time-of-flight and quadrupole mass-spectrometers, including quadrupole ion traps [18]. From such measurements, the depth of the potential well q_p can be determined.

It is also evident that the electron levels in a nuclear molecule will shift relative to the electron levels in the $_{Z+1}$B atom. In the first approximation, this nuclear molecule electron shift (NME shift) will not lead to the appearance of differences in the chemical properties of $_{Z+1}$B atom as well as of the $_{Z}$A+p nuclear molecule. The same cannot be remarked about their optical spectra. In optical measurements of atomic electron levels, the isotope shift is known which is related to the changes in the number of neutrons in the isotopes of one and the same chemical element [19]. The isotope shift consists of two parts: mass and field shifts. The mass shift between the neighbouring isotopes is connected with the change in the isotope mass by the neutron mass (~ 940 MeV). The field shift is associated with the change in the shape and volume of the nucleus when a neutron is added to the nucleus. As this takes place, the distribution of the electric charge in the nucleus or its mean-square charge radius change as well. In the nuclear molecule, the mass shift is negligibly small (~ several MeV) in comparison with the isotope mass shift. But on the other hand, the field shift in the $_{Z}$A+p nuclear molecule considerably surpasses the isotope field shift in $_{Z+1}$B. Such NME shifts can be registered using common atomic optical spectrometers. The more so they can be observed when using lasers with the variable wavelength of the radiation (for example: dye lasers), as well as in a complex with the quadrupole ion trap. Owing to the indicated reasons, it is necessary to study, first and foremost, such "chemical elements" (possible nuclear molecules) as vanadium (V = Ti+p,d), copper (Cu = Ni+p,d), silver (Ag = Pd+p,d). These chemical elements are obtained through the cold fusion reactions with the participation of hydrogen or deuterium and such basic elements as Ti (titanium), Ni (nickel), and Pd (palladium).

The nuclear molecules of vanadium, copper, silver with a proton or deuteron will have the atomic mass which is greater by one or two (*p* or *d*) than the atomic mass of stable isotopes of titanium, nickel and palladium. Vanadium, copper and silver have two stable isotopes, each: V-50, 51; Cu-63, 65; Ag-107, 109. Titanium and nickel have five stable isotopes each: Ti-46÷50; Ni-58, 60÷62, 64; and palladium has six stable isotopes: Pd-102, 104÷106, 108, 110. The nuclear molecules of V, Cu and Ag can be registered using mass spectroscopy after their chemical separation from Ti, Ni and Pd.

If the existence of nuclear molecules with a proton or a deuteron is possible, then the question about a possible existence of nuclear molecules in a pair with other nuclei, starting with helium nuclei, ^{4}He, arises. However, in condensed matter the atoms with the nucleus charge $Z \geq 2$ with thermal energy cannot lose all their electrons and enter into the RIEX-interaction with its nuclei with the nuclei of the main element, even if the potential of such an interaction is considerable. Consequently, in order to obtain heavy nuclei molecules, it is necessary to use heavy ions accelerated up to several MeV. These heavy ions

should be accelerated so that the nuclei of heavy ions could approach closely the target nuclei of the main element.

Since the exchange potential well is lower than the zero line of the potential energy, and internal potential well 2 of the nuclear molecule is less than external one 1 (**Fig. 9**), there exists a non-zero probability of spontaneous decay of a single nucleus into two cluster nuclei, and its transition into the state of a nuclear molecule consisting of two such cluster nuclei. At the transition into the state of a nuclear molecule there is a release of energy. Such energy can realize itself at the expense of neutron or gamma-quanta emission. In this case, a stable nuclear molecule is formed. In other case, the energy is released as kinetic energy of the cluster nuclei, and the nuclear molecule does not form at all. Only two nuclei are formed then. The latter case resembles the fission process of nuclei.

In nuclear physics such a notion as cluster radioactivity is known [20]. At cluster decay heavy and transuranium nuclei radiate spontaneously nuclei of light clusters which are heavier than the α-particle but lighter than the products of spontaneous fission. Up to now, over two dozens of decays have been observed experimentally for nuclei from ^{221}Fr to ^{242}Cm with the production of such clusters as: ^{14}C, ^{20}O, ^{24}Ne, ^{26}Ne, ^{28}Mg, ^{30}Mg, ^{32}Si and ^{34}Si. Since the energy of the yielding cluster in all of the decays is less than the height of the potential barrier,

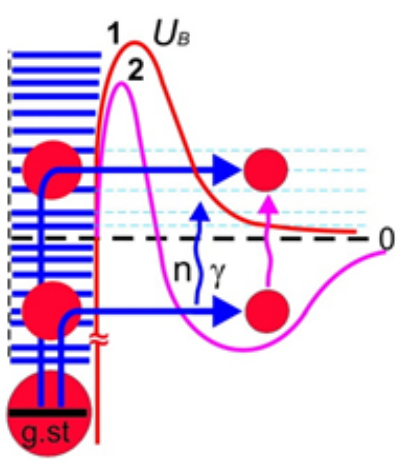

Fig. 9. *Cluster decay through barrier 1 and the formation of a nuclear molecule through barrier 2.*

$\mathbf{U_B}$, the cluster decay is due to the tunneling of the light cluster through barrier 1 (Fig. 9). The probability of such processes in relation to the main modes of decay of mother nuclei is within the range from 10^{-9} to 10^{-16}. In all of the observed cases, the residual nucleus is the double magic nucleus of lead (^{208}Pb) or its closest neighbours. Therefore, sometimes the cluster decay is called the "lead" decay. The presence of closed magic nucleon shells in the formed nuclei considerably increases the probability of the cluster decay.

The "tin" radioactivity of nuclei is predicted for the range ^{112}Ba–^{116}Ce, for which the decay with the formation of ^{12}C, ^{16}O nuclei and double magic nucleus ^{100}Sn is anticipated. By present time, the emission of ^{12}C from the ^{114}Ba nucleus with a relative probability of decay of $\sim 3.0 \cdot 10^{-5}$ is observed. It is deemed that the cluster decay, like in the case of α-radioactivity, take place in two stages: at first a cluster is formed at the surface of the mother nucleus, which then tunnels through Coulomb barrier 1 of the nucleus (Fig. 9). Since the internal potential well of the nuclear molecule is less than the outer one, the spontaneous transition is possible for the $_{56}$Ba and $_{58}$Ce nuclei into the state of nuclear molecules, $_{50}$Sn-^{12,14}C and $_{50}$Sn-^{16,18}O, correspondingly. For the same reason it is not excluded that the cluster "lead" decay occurs at first into the state with the formation of a nuclear molecule and its subsequent dissociation into clusters.

Since the cluster decay resembles the fission process when the motion of the nucleons proceeding in the mother nuclei due to its oscillation leads to the production of fragments in the course of deformation of the nucleus, the transitions of $_{56}$Ba and $_{58}$Ce nuclei into nuclear molecules, apparently, can be stimulated using gamma quanta of energy ~14-18 MeV, by exciting in $_{56}$Ba and $_{58}$Ce a giant dipole resonance. Observation of $_{50}$Sn-^{12,14}C and $_{50}$Sn-^{16,18}O nuclear molecules, as has been pointed out earlier, can be made by the mass defect or optical NME shift. Another way of observing a nuclear molecule

is the acceleration of this molecule, preferably up to one MeV/nucleon, with subsequent dissociation of the molecule at the fixed target nuclei. Dissociation of the nuclear molecule leads to the formation of two-nucleus clusters, which can be registered separately using a semiconductor detectors.

Apparently, such events were observed by the authors of paper [21] in the experiments on elastic scattering of the fragments produced in a common binary fission of atomic nuclei in a thin foil. From the obtained data, one can assume that after its binary fission the fragment can come into the state which resembles a two-nucleus system consisting of a magic cluster and a lighter cluster. A recent experiment [22] showed that the cluster decay of the fragments produced in a binary fission is characteristic of both heavy and light fragments. In a light fragment, one of the clusters forming a nuclear molecule is a deformed magic isotope, ^{85}As or ^{77}Zn; and in a heavier fragment such deformed and spherical magic isotopes can be: ^{85}As, ^{82}Ge, ^{84}Se, ^{98}Sr, ^{108}Mo, ^{121}Ag, ^{123}Cd, ^{132}Sn, ^{138}I, ^{148}Ce, ^{150}Ce. In the cluster decay of a heavy fragment, there must be "tin" radioactivity in the range of ^{144,146}Ba and ^{148,150}Ce, for which formation of molecules is expected: ^{12,14}C and ^{16,18}O with double magic spherical nucleus of ^{132}Sn ($T_{1/2} = 40$ *s*).

As a result:

- The resonant exchange interaction is realized between any objects, A and B, which possess resonant *R*-states belonging to a compound system. Consequently, the resonant interaction is an exchange interaction. At resonant interaction between the objects, a supplementary exchange energy is produced, which attracts them to each other, thus increasing the cross section of the reaction between the interacting objects.
- The resonant exchange interaction explains how the reactions of cold fusion on protons and deuterons take place.
- The resonant exchange interaction predicts the existence of nuclear molecules.

4. RESONANT INTERFERENCE EXCHANGE INTERACTION

4.1. Two-Slit Interference

Resonant interference exchange interaction passes between the particle at its wavelength and the resonant *R*-state which is had by any object (*R*-object). The RIEX-interaction can take place in the condensed matter, with a large concentration of identical *R*-objects. If the distance between the *R*-objects is less than the given wavelength of the particle $K^4\lambda$ with the affinity coefficient *K*, then the particle excites all of the *R*-objects in the sphere with the radius $K^4\lambda$. In such a case the wave functions which arose for multiple *R*-objects, interact simultaneously both with the wave functions of the particle and with each other. The *R*-objects have additional exchange interaction. Thus, the RIEX-interaction allows one to produce correlated ensembles of identical particles and objects.

When in the condensed medium all identical *R*-objects move, they will affect chaotically the travelling particle. If the objects are fixed, their total influence on the particle will become quite definite, and it will change in dependence from the location of the *R*-objects and from the direction of the particle motion.

Let us fix two *R*-objects which are equidistant from the particle that is moving opposite to them. The wave functions of the two *R*-objects will interfere with each other, producing an interference field. The particle entering into a RIEX-interaction with the *R*-objects will deviate to one side or another due to this interference field. Now, let us replace these two *R*-objects with two *R*-resonators. In resonator cavities tuned to the required wavelength of the particle, oscillations are excited which interfere and resonantly interact with the particle. This RIEX-interaction also deviates the particle from its way.

Two slits with the parameters corresponding to the oncoming particle, similarly to two resonator cavities, produce interference fields in front of the particle travelling opposite to them

and behind the particle that is moving away from two-slits. The particle while interacting with the interference fields produced by the two-slits will make an interference picture on the screen behind the slits. When doing so, the particle will travel through one slit. The slits interacting with the particle represent active elements. Thus, the paradox of travelling by the quantum particle simultaneously through two slits is annihilated.

4.2. Transnuclei, Nuclear Transmolecules and Transmutation Reactions

The multiple and variable experiments in low-energy transmutation of chemical elements prompt us that the condensed matter is ionized when externally influenced, and at a certain charge density, stable local electron-ion formations are produced inside it − capsules with a strong magnetic field **B** inside (> 30*T*). In the strong magnetic field **B**, the atomic electrons are paired into orthobosons, and the atoms are inevitably transformed into transatoms.

The electronic orthobosons make the spin Bose-Einstein condensate in the atom or the torsem-condensate. The magnetic moments of the electrons, μ_e, in the torsem condensate are oriented in one direction, and they generate inside and around the transatom the ultrastrong, directional, inhomogenous and anisotropic magnetic field $\mathbf{B}_S \sim 10^5$–10^{10} T [5, 23]. The internal ultrastrong magnetic field $\mathbf{B}_S$, while interacting with the magnetic and magnetic orbital moments of the nucleons in the nucleus, change the nucleus structure by transforming it into a transnucleus.

In a strong magnetic field, the atom from its "amorphous state" is transformed into a well-ordered magnetic "crystal", that is into a transatom. Being in the state of the torsem condensate, the transatom practically loses its individuality. The transatoms with an even number of the electrons begin to resemble inert gases, while uneven transatoms resemble alkaline chemical elements with one outer electron. The difference between the transatoms lies in the number of orthobosons residing at the electron shells [23].

The same occurs with the nucleus but already in an ultrastrong magnetic field of the torsem condensate. The transnucleus is an ordered nuclear magnetic "crystal". The nucleons in the nucleus, just like the electrons in an atom, can produce nucleon orthobosons: proton-proton and neutron-neutron ones. Proton-proton and neutron-neutron orthobosons form nucleon shells. The transnuclei lose their individuality. Their structures begin to resemble each other. The structure of a light transnucleus will be identical to the component of the structure of a heavier transnucleus. These identical parts of the transnuclei can enter into an exchange interaction.

The ultrastrong magnetic fields of orthobosons and their torsem condensate attract transatoms to each other. The torsem condensate of transatoms get collectivized. The transnuclei of the transatoms get collectivized as well. Binuclear and multinuclear molecules called transmolecules are produced. **Fig. 10** depicts as an example the formation of a sodium transmolecule, $_{11}$Na, from the transatoms of boron, $_5$B, and carbon, $_6$C. Transmolecules consist of transnuclei, parts of which are identical to each other. The transnuclei in the transmolecule enter into the low-energy multinuclear reactions of transmutation. As a result of transmutation reactions, other chemical elements are produced. The atomic nuclei of these chemical elements are non-radioactive since the weak exchange interaction and electronic orthobosons take part in the transmutation reactions.

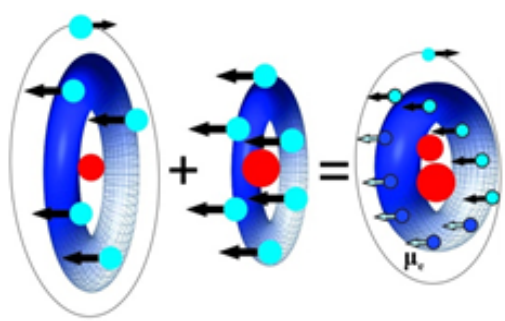

Fig. 10. *The formation of sodium transmolecule from boron and carbon transatoms.*

The transatoms with transnuclei are steady, stable formations. However, being in the environment, the transatoms using their ultrastrong magnetic fields transform common atoms into transatoms at collisions. The transatoms form transmolecules at once, which enter into the transmutation reactions with its transnuclei. The products of transmutation reactions, if they are not in a strong magnetic field, are found as common atoms with common nuclei. Thus, in a medium of common atoms the transatoms with the transnuclei are non-steady, non-stable formations.

The experiments and theoretical calculations in low-energy transmutation of chemical elements have shown that in the yielding reaction channel there is such an ensemble of new nuclei which is different, minimally, in the total mass from the total mass of the ensemble of nuclei at the entrance channel. In other words, the energy produced in the transmutation reactions is not large and amounts from tens of keV up to several MeV. In usual nuclear reactions, the greater the difference in the energies between the initial and final states, the greater is the probability of this reaction. The reactions with the participation of two and more objects with a small production of energy proceed with a larger cross section only in the case when they have a resonant character; in other words, if there is resonant interference exchange interaction between them. Consequently, low-energy multinuclear reactions of transmutation of chemical elements take place at the expense of the RIEX-interaction.

5. CONCLUSION

The Universe consists of identical particles, mostly of fermions, $s = 1/2$: protons, neutrons, electrons. They, in their turn, form a great number of varied and, at the same time, similar, in a certain sense "identical" objects and a variety of different and, at the same time, identical systems. Each system is composed of interacting objects in it, which simultaneously present "a system". Each such system enters as an object into a more unified system. Among the particles, objects and systems there exist all types of fundamental interactions, including the RIEX-interaction.

The objects where the compound systems have resonance states, come into a resonant interaction, but in fact into the resonant interference exchange interaction. The RIEX-interaction attracts the objects to each other. Thus, knowing the properties of the object, its resonances, one can determine its location by coming into the RIEX-interaction with it. Using the RIEX-interaction one can "find a black cat in a dark room".

As a rule, if some process passes with a surprisingly high yielding cross section, it is necessary to search for the resonance for the interacting objects.

The resonances "permeate" the entire Universe, starting with the elementary particles up to complex social systems. The more complex is the system, the more resonant states and resonant vibrations it possesses. The RIEX-interaction does not only join the objects into systems, but when doing this it simultaneously makes the choice and natural selection of suitable objects from a greater number of other different objects. This mechanism is vitally important for the biological systems, for instance, in replication of the DNA molecule.

The RIEX-interaction is universal since it includes all of the fundamental interactions. The RIEX-interaction creates more complex systems from isolated objects, and thus prevents their destruction. So, the resonance interference exchange interaction is defined as AntiEnthropy one.

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