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Weak Interactions as Essence of LENR

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***Abstract*—Low mass of neutrinos (antineutrinos) makes possible their intensive generation as a result of matter particles collisions during thermal motion. Arising neutrinos (antineutrinos) have energy of about 0.1 eV. With such energy, de Broglie length is about 5 microns. It means that a huge number of atoms are involved in weak nuclear interactions, which makes the effects of nuclear transformations with the participation of neutrinos (antineutrinos) really observable. Consideration of thermal generation of neutrinos as the basis of nuclear transformations in the LENR process allows us to explain a number of features of this phenomenon.**

I. Introduction

An extensive class of phenomena that are called “low-energy nuclear reactions” (LENR) or “cold nuclear transmutations” (CNT) or outdated “cold synthesis” are in fact neither low-energy (very much energy is released) or cold (is it possible to call a cold process occurring at temperatures of 1000 degrees Celsius?). The unsatisfactory nature of the terms used is obvious to all researchers of this phenomenon. But until the physical mechanism of this phenomenon is clarified, only conditional terminology is possible. In this paper we will use the most popular term “LENR”.

LENR is very diverse. These are processes in metals with hydrogen dissolved in them. These are processes in plasma, in a gas discharge, and even in biological systems. At first glance, these processes have nothing in common. But on closer examination, you can see four features that unite them.

The first feature is that they have a quite tangible energy threshold. This is especially clearly seen in the example of nickel-hydrogen reactors, in which intense excessive heat generation occurs only at temperatures above 1200°C [1], [2], i.e. when the average energy of particles of a substance during thermal motion exceeds 0.1 eV. In electric plasma reactors [3], [4], the temperature reaches several thousand degrees (tenths of eV). In installations with plasma of a glowing gas discharge [5], [6], the electron energy is of the order of 1 eV. At first glance, the processes in which LENR signs are detected at room temperature (electrolysis [7], biology [8], [9]) are an exception to this rule. But in reality, energy exchange of about 1 eV is characteristic of acts of energy exchange in both electrochemistry and cell metabolism processes.

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The second feature is that the LENR processes occur in a fairly dense medium (solid, liquid, or dense plasma).

The third feature is the large variety of nuclides arising in the LENR process.

The fourth feature is the absence (or very low intensity) of hard nuclear radiation (neutrons, gamma quanta), which, it would seem, inevitably should occur during nuclear transformations.

These features may indicate the search path of the physical mechanism LENR. We must look for a mechanism that manifests itself at energies greater than 0.1 eV, which gives a large variety of nuclides, and changes at the nuclear level do not cause the appearance of hard radiations. In addition, the mechanism sought must solve the problem of the “Coulomb barrier,” since energies of the order of 1 eV are completely insufficient to overcome it in the process of nuclear collisions.

In a number of papers it was suggested that in order to solve the problem of explaining LENR, it is necessary to involve weak nuclear interactions [10], [11], [12], [13]. I will try to show that in this way one can explain all the indicated features of the LENR. I note that in weak interactions (beta processes) the problem of the Coulomb barrier does not exist.

II. LENR threshold

The presence of neutrinos (antineutrinos) is a prerequisite for nuclear transformations associated with weak interactions to occur. Since neutrinos have a very small mass (currently it is believed that the mass of electron neutrino and antineutrino does not exceed 0.28 eV [14]), they can, although with a low probability, result from inelastic collisions of particles of a substance (electrons, ions, neutral atoms) during their thermal motion. Basically, in inelastic collisions of particles, photons are born, not neutrinos. Born photons, if they have enough energy, can with a small probability of decay into a pair of neutrino-antineutrino.

Since there are no accurate data on the neutrino mass, for estimated calculations we will assume that the minimum energy for the formation of a neutrino-antineutrino pair is 0.5 eV. Average energy of 0.5 eV have particles in the body heated to 3200°C. Recall that the average energy of thermal motion $\overline{\varepsilon} = 1,5kT$ (k=1,38·10^{-23}J/K is the Boltzmann constant, T=t(°C)+273,15 is the absolute temperature). Some particles have this and higher energy even at lower temperatures. Using the energy distribution function of particles during thermal motion [15]

$$f(\varepsilon) = \frac{2\sqrt{\varepsilon}}{\sqrt{\pi (kT)^3}} \exp\left(-\frac{\varepsilon}{kT}\right),$$

it is possible to find the temperature dependence of the fraction of particles having an energy above a given one. For threshold energy of 0.5 eV, this dependence is shown in Fig. 1. At room temperature, the proportion of such particles is 10^{-8}. A noticeable proportion of particles with energy above 0.5 eV appears only at a temperature of about 1000°C. At a temperature of 1600°C such particles are already 10%, and at a temperature of 4500°C 50%. Thus, under the assumptions made, the threshold for thermal generation of neutrino-antineutrino pairs is about 1000°C.

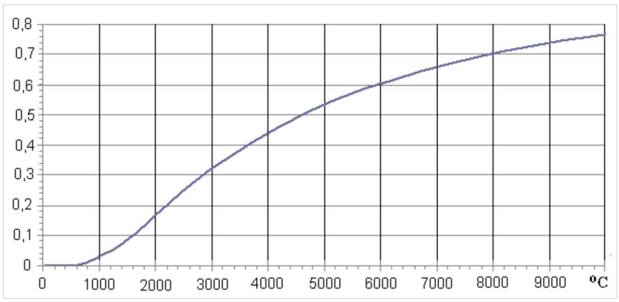

Figure 1. Proportion of particles with energy above 0.5 eV, depending on temperature.

III. Need for a dense environment

At present, the level of knowledge about the properties of neutrinos is insufficient to reliably determine the probability of the formation of neutrinos and antineutrinos during thermal collisions of particles of matter. It is clear only that the probability of this is small. A small probability is compensated by a large number of collisions. We estimate the number of collisions per second during thermal motion in metals. Most often in metals electrons collide with atoms. The path length between collisions is about 10^{-8} m. The speed of movement of electrons at a temperature of 2000K is about $2{\cdot}10^5$ m/s [16, p.117]. Consequently, an electron with its thermal motion experiences $2{\cdot}10^{13}$ collisions per second. Considering that the number of free electrons in 1 cm^3 of metal is about 10^{23} [16, p.115], we find the number of collisions per second in 1 $cm^3$of metal: $2{\cdot}10^{36}$.Such a huge number of collisions allow to suggest that in sufficiently hot metals, neutrinos and antineutrinos appears with an intensity sufficient to initiate nuclear transformations that give a significant energy release even with very low probabilities of neutrino-related processes. Suppose that only one of 10^{10} collisions produces a pair of neutrino-antineutrinos, and only one of 10^{10} neutrinos or antineutrinos causes nuclear transformation. Even with such huge losses, 1 cm^3 of hot metal produces $2{\cdot}10^{16}$ nuclear transformations per second. In each act of such transformations, about 1 MeV is distinguished. Since 1 J is equivalent to $6{,}25{\cdot}10^{12}$ MeV, produced power will be approximately 2 kW.

We make a similar estimate for a gas heated to a temperature sufficient for thermal generation of neutrinos (several thousand °C). In a gas, even at such temperatures, number of electrons and ions are much smaller than neutral atoms (molecules), therefore atoms (molecules) collide predominantly. The speed of their movement is about 10^3 m/s, and the mean free path before the collision at atmospheric pressure is about 10^{-7} m [17]. Consequently, an atom (molecule) experiences about 10^{10} collisions per second. 1 cm^3 of hot gas at atmospheric pressure contains about 10^{19} atoms (molecules). It takes about 10^{29} collisions per second, which is 7 orders of magnitude smaller than electrons in metals.

Thus, in a gas heated to a temperature of several thousand degrees, thermal generation of neutrinos and antineutrinos, although possible, occurs with an intensity that is many orders of magnitude lower than in metals. Intensive generation requires a hot dense medium with a high content of free electrons. In addition to metals, such a medium is high-density plasma, which briefly appears, for example, in explosions of metallic conductors or when a sufficiently strong pulsed energy release in liquids.

IV. Multikernel interactions and the variety of emerging nuclides

As indicated in [11], [12], [13], a huge variety of nuclides arising in the LENR process can be achieved if several nuclei are involved in the interaction at once. The article [13] reported on computer calculations of possible options for energetically beneficial nuclear transformations of two stable nuclides to two other stable nuclides with the participation of electrons and neutrinos (antineutrinos), in which the laws of conservation of electric, baryonic and lepton charges are satisfied. Computed:

rearrangements of nucleons with electron absorption:

$$(A1, Z1) + (A2, Z2) + e^- + \tilde{\nu} \rightarrow (A3, Z3) + (A4, Z4) + Q$$
$$A3 + A4 = A1 + A2, \quad Z3 + Z4 = Z1 + Z2 - 1,$$

for example, ${}^{60}Ni + {}^{1}H + e^- + \tilde{\nu} \rightarrow {}^{4}He + {}^{57}Fe + 0{,}569\text{MeV}$,

and rearrangements of nucleons with the release of electrons:

$$(A1, Z1) + (A2, Z2) + \nu \rightarrow (A3, Z3) + (A4, Z4) + e^- + Q$$
$$A3 + A4 = A1 + A2, \quad Z3 + Z4 = Z1 + Z2 + 1,$$

for example, ${}^{61}Ni + {}^{64}Ni + \nu \rightarrow {}^{63}Cu + {}^{62}Ni + e^- + 0{,}995\text{MeV}$.

263546 variants of transformations of the first type and 433536 variants of the second type were found. The number of options identified is huge. But this is not all possibilities. More than two nuclei can be involved in processes of this kind, processes involving several electrons are possible.

The processes associated with weak interactions are extremely unlikely if the neutrinos (antineutrinos) participating in them have an energy of the order of 1 MeV and higher. Such neutrinos (antineutrinos) arise in the process of beta decays or are generated at accelerators. But when they occur as a result of thermal collisions, the situation is much better. Such neutrinos (antineutrinos) have a kinetic energy of no more than tenths of an eV. Unlike the “nuclear” neutrinos, they have a de Broglie wavelength considerably exceeding the interatomic distances. Neutrino with a mass of 0.28 eV and a kinetic energy of 0.1 eV have de Broglie wavelength about 5 microns. This means that the interaction region covers a huge number of atoms (of the order of 10^{13} in a solid or liquid substance), which makes transformations that capture many atoms and nuclei possible, with the result that even unlikely processes become noticeable [18], [19].

V. Absence of hard nuclear radiation

In the described mechanism, the rearrangement of nucleons occurs without the introduction of energy, which could cause the excitation of nuclear levels, the emission of which could lead to the emission of gamma quanta. The deficiency of the introduced energy leads to the fact that of all the possible variants of transformations, there are realized those at which the most stable nuclides are formed, not prone to alpha or beta radioactivity, or to the emission of neutrons. The energy released is realized in the form of the kinetic energy of the resulting nuclides. Despite the fact that they can have energy up to several MeV, when they are braked, hard radiation does not occur, since massive charged particles lose their energy even at high energies mainly as a result of ionization and excitation of atoms of the medium in which they move [20]. When this occurs, electromagnetic radiation is radiated, but ”soft”, with the energy of quanta up to several keV. In addition, the emission of “soft” quanta occurs when the deformed electron shells of the resulting nuclides are normalized.

VI. Conclusion

Neutrinos are considered usually to be almost elusive, they manifested only in the most complex experiments on huge installations. But it does not take into account that the properties of neutrinos at very low energies are different from the properties of “nuclear” neutrinos, like, for example, light differs from gamma radiation or helium gas differs from alpha particles. Coverage of a huge number of atoms by Interaction leads to a significant increase in the interaction efficiency of neutrinos with matter, to the involvement in the nuclear transformations of many atoms at once. This allows us to explain a number of features of LENR.

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