New Cooperative Mechanisms of Low Energy Nuclear Reactions Using Superlow Energy External Field

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Abstract

We propose a new mechanism of LENR: cooperative processes in the whole system, nuclei + atoms + condensed matter, can occur at a smaller threshold energies than the corresponding ones on free constituents. The cooperative processes can be induced and enhanced by low energy external fields. The excess heat is the emission of internal energy and transmutations at LENR are the result of redistribution of inner energy of the whole system.

1 Introduction

A review of possible stimulation mechanisms of LENR (low energy nuclear reaction) is presented in [2]. We have concluded that transmutation of nuclei at low energies and excess heat are possible in the framework of the known fundamental physical laws – the universal resonance synchronization principle [1], and different enhancement mechanisms of reaction rates based on it are responsible for these processes [2]. The super low energy of external fields, the excitation and ionization of atoms may play the role of a trigger for LENR. [3]. We argue that the cooperative mechanism can explain how the electron volt domain can influence the nuclear mega electron volt domain [3]. Nuclear physicists are absolutely sure that this is cannot happen. Investigation of this phenomenon requires the knowledge of different branches of science: nuclear and atomic physics, chemistry and electrochemistry, condensed matter and solid state physics … The puzzle of poor reproducibility is explained by the fact that LENR occurs in open systems and it is extremely sensitive to parameters of external fields and systems. The classical reproducibility principle should be reconsidered for LENR experiments. Poor reproducibility and unexplained results do not mean that the experiment is wrong. Our main conclusion is: LENR may be understood in terms of the known fundamental laws without any violation of the basic physics. The fundamental laws of physics should be the same in micro- and macrosystems.

Let us start with the description of the hydrogen atom structure in different models.

1.1 The Hydrogen Atom

We will describe very briefly the structure of a hydrogen atom using standard basic physics that is well established, both theoretically and experimentally in micro- and macrosystems.

1.2 The Bohr Model

At the end of the 19th century it was established that the radiation from hydrogen was emitted at specific quantized frequencies. Niels Bohr developed the model to explain this radiation using four postulates:

- An electron in an atom moves in a circular orbit about the nucleus under the influence of the Coulomb attraction between the electron and the nucleus, obeying the laws of classical mechanics.
- Instead of the infinity of orbits which would be possible in classical mechanics, it is only possible for an electron to move in an orbit for which its orbital angular momentum $L$ is
integral multiple of $\hbar$:

$$L = nh, \quad n = 1, 2, 3, \ldots$$  \hfill (1)

- Despite the fact that it is constantly accelerating, an electron moving in such allowed orbit does not radiate electromagnetic energy. Thus, its total energy $E$ remains constant.

Electromagnetic radiation is emitted if an electron, initially moving in an orbit of total energy $E_i$, discontinuously changes its motion so that it moves in an orbit of total energy $E_f$. The frequency $\nu$ of the emitted radiation is equal to the quantity

$$\nu = \frac{E_i - E_f}{\hbar}$$  \hfill (2)

where $\hbar$ is Planck's constant. The electron is held in a stable circular orbit around a nucleus. The Coulomb force is equal to the centripetal force, according to Newton's second law

$$\frac{e^2}{r^2} = \frac{mv^2}{r},$$  \hfill (3)

where $r$ is the radius of the electron orbit, and $v$ is the electron speed. The force is central; hence from the quantization condition (1) we have

$$L = |\vec{p} \cdot \vec{r}| = mvr = nh$$  \hfill (4)

After solving equations (3) and (4) we have

$$v = \frac{e^2}{nh}, \quad r = \frac{n^2 \hbar^2}{me^2} = n^2 a_0.$$  \hfill (5)

Following equation (3) the kinetic energy is equal to

$$E_k = \frac{1}{2}mv^2 = \frac{e^2}{2r},$$  \hfill (6)

and hence the total energy is

$$E = E_k + V = \frac{e^2}{2r} - \frac{e^2}{r} = -\frac{e^2}{2r}.$$  \hfill (7)

Having $r$ from equation (5) one can write the expression for the energy levels for hydrogen atoms

$$E = -\frac{me^4}{2\hbar^2 n^2},$$  \hfill (8)

the same results were further obtained by quantum mechanics.

Using the angular momentum quantization condition $L = pr = nh / 2\pi$ and Louis de Broglie's relationship $p = h / \lambda$ between momentum and wavelength one can get

$$2\pi r = n\lambda.$$  \hfill (9)

⊗ This means that the circular Bohr orbit is an integral number of the de Broglie wavelengths. The Bohr model is actually only accurate for a one-electron system.

1.3 The Hydrogen Atom in Classical Mechanics

Is it possible to understand some properties of a hydrogen atom from classical mechanics? The Hamiltonian for a hydrogen atom is

$$H = \frac{m_p \dot{\vec{r}}_p^2}{2} + \frac{m_e \dot{\vec{r}}_e^2}{2} - \frac{e^2}{|\vec{r}_p - \vec{r}_e|}.$$  \hfill (10)

All notation is standard. The definition of the center of mass is

$$m_p \vec{r}_p + m_e \vec{r}_e = 0,$$  \hfill (11)

and the relative distance between electron and proton is
\[ r = \vec{r}_p - \vec{r}_e. \]  

Equations (10)-(12) lead to the results:

\[ \vec{r}_p = \frac{m_e}{m_p + m_e} \vec{r}, \quad \vec{r}_e = -\frac{m_p}{m_p + m_e} \vec{r}, \]

\[ H = \frac{\mu \dot{r}^2}{2} - \frac{e^2}{r}, \]

where

\[ \mu = \frac{m_pm_e}{m_p + m_e}. \]  

The Hamiltonian (14) coincides with the Hamiltonian for the fictitious material point with reduced mass \( \mu \) moving in the external field \(-e^2/r\). If we known the trajectory of this fictitious particle \( \vec{r} = \vec{r}(t) \) then we can reconstruct the trajectories of electron and proton using equations (13)

\[ \vec{r}_p (t) = \frac{m_e}{m_p + m_e} \vec{r}(t), \quad \vec{r}_e (t) = -\frac{m_p}{m_p + m_e} \vec{r}(t). \]

It is evident from (16) that the proton and electron move in the opposite directions synchronously. So the motions of proton, electron and their relative motion occur with equal frequency

\[ \omega_p = \omega_e = \omega_\mu, \]

over the closed trajectories scaling by the ratio

\[ \frac{v_e}{v_p} = \frac{m_p}{m_e}, \quad \frac{v_e}{v_\mu} = \frac{m_\mu}{m_e}, \quad \frac{v_\mu}{v_p} = \frac{m_p}{m_\mu}. \]

I.A. Schelaev [6] proved that the frequency spectrum of any motion on ellipse contains only one harmonic.

We can get from (16) that

\[ \vec{P}_p = \vec{P}, \quad \vec{P}_e = -\vec{P}, \]

where \( -\vec{P} = m_1 \dot{r}_1 \). All three impulses are equal to each other in absolute value, which means the equality of

\[ \lambda_D(p) = \lambda_D(e) = \lambda_D(\mu) = h/P. \]

Conclusion:

Therefore, the motions of proton and electron and their relative motion occur with the same FREQUENCY, IMPULSE (linear momentum) and the de Broglie WAVELENGTH. All motions are synchronized and self-sustained. Therefore the whole system -hydrogen atom is nondecomposable to the independent motions of proton and electron despite the fact that the kinetic energy ratio of electron to proton is small:

\[ \frac{E_k(e)}{E_k(p)} = 4.46 \times 10^{-4}. \]

This means that the nuclear and the corresponding atomic processes must be considered as a unified entirely determined whole process.
For example, V.F. Weisskopf \[8\] came to the conclusion that the maximum height \(H\) of mountains in terms of the Bohr radius \(a\) is equal to

\[
\frac{H}{a} = 2.6 \times 10^{14},
\]

and water wave lengths \(\lambda\) on the surface of a lake in terms of the Bohr radius is equal to

\[
\frac{\lambda}{a} \approx 2\pi \times 10^7.
\]

Let us introduce the quantity \(f = rv\) which is the invariant of motion, according to Kepler’s second law, then

\[
\mu v = \frac{\mu vr}{r} = \frac{\mu f}{r},
\]

and we can rewrite equation (14) in the following way:

\[
H = \frac{\mu f^2}{2r^2} - \frac{e^2}{r},
\]

We can obtain the minimal value of (21) by taking its first derivative over \(r\) and setting it equal to zero. The minimal value occurs at

\[
r_0 = \frac{\mu f^2}{e^2},
\]

and the result is

\[
H_{\text{min}} = E_{\text{min}} = -\frac{e^4}{2 \mu f^2}.
\]

The values of invariant of motion \(\nu f\) (in MeV*s) can be calculate from (23) if we require the equality of \(E_{\text{min}}\) to the energy of the ground state of a hydrogen atom

\[
\mu f = \mu vr = 6.582118 \times 10^{-22} = h,
\]

Conclusion:

⊗ The Bohr quantization conditions were introduced as a hypothesis. We obtain these conditions from a classical Hamiltonian requiring its minimality. It should be strongly stressed that no assumption was formulated about trajectories of proton and electron. We reproduced exactly the Bohr result and modern quantum theory. The Plank constant \(h\) is the Erenfest adiabatic invariant for a hydrogen atom: \(\mu vr = h\).

Let us briefly review our steps:

- We used a well-established interaction between proton and electron.
- We used a fundamental fact that the total energy=kinetic energy + potential energy.
- We used Kepler’s second law.
- We used usual calculus to determine the minimum values of \(H\).
- We required the equality of \(E_{\text{min}}\) to the energy of the ground state of hydrogen atom.

Classical Hamiltonian + classical interaction between proton and electron + classical second Kepler law + standard variational calculus, together these well established steps in macrophysics reproduce exactly the results of microphysics; that is, the Bohr model and modern quantum theory (Schrödinger equation). We have not done anything spectacular or appealed to any revolutionary and breakthrough physics.

Using the Newton equation with well established interactions M. Gryzinski \[7\] proved that atoms have the quasi-crystal structure with definite angles: 90°, 109° and 120° which are the well-known angles in crystallography.
2 Nuclei and Atoms as Open Systems

1) LENR may be understood in terms of the known fundamental laws without any violation of basic physics. The fundamental laws of physics should be the same in micro- and macrosystems.

2) Weak and electromagnetic interactions may show a strong influence of the surrounding conditions on the nuclear processes.

3) The conservation laws are valid for closed systems. Therefore, the failure of parity in weak interactions means that the corresponding systems are open systems. Periodic variations (24 hours, 27, and 365 days in beta-decay rates indicate that the failure of parity in weak interactions has a cosmophysical origin. Modern quantum theory is the theory for closed systems. Therefore, it should be reformulated for open systems. The closed systems are idealization of nature, they do not exist in reality.

4) The universal resonance synchronization principle is a key issue to make a bridge between various scales of interactions and it is responsible for self-organization of hierarchical systems independent of substance, fields, and interactions. We give some arguments in favor of the mechanism – ORDER BASED on ORDER, declared by Schrödinger in [4], a fundamental problem of contemporary science.

5) The universal resonance synchronization principle became a fruitful interdisciplinary science of general laws of self-organized processes in different branches of physics, because it is the consequence of the energy conservation law and resonance character of any interaction between wave systems. We have proved the homology of the atom, molecule and crystal structures including living cells. Distances of these systems are commensurate with the de Broglie wavelength of an electron in the ground state of a hydrogen atom, it plays the role of the standard distance, for comparison.

6) First of all, the structure of a hydrogen atom should be established. A proton and electron in a hydrogen atom move with the same frequency that creates attractive forces between them; their motions are synchronized. A hydrogen atom represents the radiating and accepting antennas (dipole) interchanging energies with the surrounding substance. The sum of radiate and absorb energy flows by electron and proton in a stable orbit is equal to zero [5] – the secret of success of the Bohr model (nonradiation of the electron in a stable orbit). “The greatness of mountains, the finger sized drop, the shiver of a lake, and the smallness of an atom are all related by simple laws of nature” (Victor F. Weisskopf) [8].

7) These flows create standing waves due to the resonance synchronization principle. A constant energy exchange with substances (with universes) create stable auto-oscillation systems in which the frequencies of external fields and all subsystems are commensurate. The relict radiation (the relict isotropic standing waves at T=2.725 K – the Cosmic Microwave Background Radiation (CMBR)) and many isotropic standing waves in cosmic medium [9] should be results of self-organization of the stable hydrogen atoms, according to the universal resonance synchronization principle, that is a consequence of the fundamental energy conservation law. One of the fundamental predictions of the Hot Big Bang theory for the creation of the Universe is CMBR.

8) The cosmic isotropic standing waves (many of them are not discovered yet) should play the role of a conductor responsible for stability of elementary particles, nuclei, atoms,…galaxies ranging in size more than 55 orders of magnitude.

9) The phase velocity of standing microwaves can be extremely high; therefore all objects of the Universe should get information from each other almost immediately using phase velocity.

The aim of this paper is to discuss the possibility of inducing and controlling nuclear reactions at low temperatures and pressures by using different low energy external fields and various physical and chemical processes. The main question is the following: is it possible to enhance LENR rates by using low and extremely low energy external fields? The review of
possible stimulation mechanisms is presented in [2, 5]. We will discuss new possible ways to enhance LENR rates in condensed matter.

3 LENR in Condensed Matter

The modern understanding of the decay of the neutron is

\[ n \rightarrow p + e^- + \bar{\nu}_e, \]  

(25)

The energetics of the decay can be analyzed using the concept of binding energy and the masses of particles by their rest mass energies. The energy balance from neutron decay can be calculated from the particle masses. The rest mass difference \((0.7823\,\text{MeV}/c^2)\) between neutron and (proton + electron) is converted to the kinetic energy of proton, electron and neutrino. The neutron is about 0.2% more massive than a proton, an energy difference is \(1.29\,\text{MeV}\). A free neutron will decay with a half-life of about 10.3 minutes. Neutron in a nucleus will decay if a more stable nucleus results otherwise neutron in a nucleus will be stable. A half-life of neutron in nuclei changes dramatically and depends on the isotopes.

The capture of electrons by protons is possible

\[ p + e^- \rightarrow n + \nu_e, \]  

(26)

but for free protons and electrons this reaction has never been observed which is the case in nuclear + atomic physics. The capture of electrons by protons in a nucleus will occur if a more stable nucleus results.

3.1 Cooperative Processes

The processes (25) and (26) in LENR occur with individual nucleons and electrons. In these cases the rest mass difference is equal to \(0.7823\,\text{MeV}/c^2\). In the case of neutron decay the corresponding energy \((Q = 0.7823\,\text{MeV})\) is converted to kinetic energies of proton, electron, and antineutrino. In the case of the capture of electrons by protons the quantity \(Q = 0.7823\,\text{MeV}\) is a threshold electron kinetic energy under which the process (26) is forbidden for free proton and electron.

We have formulated the following postulate:

⊗ The processes (25) and (26) in LENR occur in the whole system: cooperative processes including all nucleons in nuclei and electrons in atoms, in condensed matter. In these cases the threshold energy \(Q\) can be drastically decreased by internal energy of the whole system or even more - the electron capture by proton can be accompanied by emission of internal binding energy - main source of excess heat phenomenon in LENR.

The processes (25) and (26) are weak processes. A weak interaction which is responsible for electron capture and other forms of beta decay is of a very short range. So the rate of electron capture and emission (internal conversion) is proportional to the density of electrons in nuclei. This means we can manage the electron-capture (emission) rate by the change of the total electron density in the nuclei using different low energy external fields. These fields can play the role of triggers for extracting the internal energy of the whole system or subsystems, changing quantum numbers of the initial states in such a way that forbidden transitions become allowed ones. The distances between proton and electron in atoms are of the order \(10^{-6} - 10^{-5}\) cm and any external field decreasing these distances, even for a small value, can increase the process (26) in nuclei in an exponential way. Therefore, the influence of an external electron flux (discharge in condensed matter: breakdown, spark and ark) on the velocity’s processes (25) and (26) can be of great importance.
The role of external electrons is the same as the catalytic role of neutrons in the case of the chain fission reactions in nuclei: neutrons bring to nuclei binding energies (about 8 MeV) which enhance the fission rates by about 30 orders.

4 Predicted Effects and Experimentum Cruices

Postulated enhancement mechanism of LENR by external fields can be verified by the Experimentum Cruices. We [5] predicted that natural geo-transmutation in the atmosphere and earth occur in the regions of a strong change in geo-, bio-, acoustic- and electromagnetic fields.

The various electrodynamic processes at thunderstorms are responsible for different phenomena: electromagnetic pulses, $\gamma$-rays, electron fluxes, neutron fluxes, and radioactive nuclei fluxes.

4.1 Neutron Production by Thunderstorms

The authors of [15] concluded that a neutron burst is associated with lighting. The total number of neutrons produced by one typical lighting discharge was estimated as $2.5 \times 10^{10}$.

4.2 Production of Radiocarbon and Failing of Radiocarbon Dating

The radiocarbon dating is based on the decay rate of radioactive isotope $^{14}C$ which is believed to be constant irrespective of the physical and chemical conditions. The half-life of radiocarbon $^{14}C$ is 5730 years. A method for historical chronometry assuming was developed that the decay ratio of $^{14}C$ and its formation are constant in time. It was postulated that $^{14}C$ is formed only by the cosmic ray neutrons

$$^{14}N(n, p)^{14}C.$$ (27)

Radiocarbon dating is widely used in archeology, geology, antiquities,... There are over 130 radiocarbon dating laboratories. The radiocarbon method of dating was developed by Willard F. Libby who was awarded the Nobel prize in Chemistry for 1960.

The radiocarbon method does not take into account the following facts which have been established recently:

- The neutron production by thunderstorms [15].
- The Production of radiocarbon by lighting bolts [13].

Let us consider the reaction

$$^{14}N + e^- \rightarrow ^{14}C + \nu_e,$$ (27a)

the $T_h(e) = 165.41 keV$ is the threshold energy which should be compared with 782.3 keV for process (26). Production of radiocarbon by lighting bolts was established in [13]. Unfortunately, this means FAILING of RADIOCARBON DATING.

4.3 Production Radiophosphorus by Thunderstorms

The life-times of $^{32}_{15}P$ and $^{33}_{16}P$ are equal to 14.36 and 25.34 days, respectively. They were found in rain-water after thunderstorms [12]. Production of the radiophosphorus by thunderstorms can be understood in the following way:

$$^{32}_{15}S + e^- \rightarrow ^{32}_{15}P + \nu_e,$$ (28)

$$^{33}_{16}S + e^- \rightarrow ^{33}_{16}P + \nu_e,$$ (29)

thresholds of these processes are equal to 1.710 and 0.240 MeV, respectively. The precipitation of MeV electrons from the inner radiation belt [14] and enhancement of the processes by lighting are possible.
4.4 LENR Stimulated by Condensed Matter Discharge

Let us consider the condensed matter discharge (breakdown, spark and arc) using the different electrodes. There are the following processes:

1. The electrode is Ni. Orbital or external electron capture

\[ ^{58}\text{Ni}(68.27\%) + e^{-} \rightarrow ^{58}\text{Co}(70.78\text{days}) + \nu_e, \]  

The threshold \( Q_1 = 0.37766\text{keV} \) of this reaction on Ni should be compared with the threshold \( Q_2 = 0.7823\text{keV} \) for electron capture by free protons: \( Q_1 / Q_2 \approx 2 \). The velocity of orbital electron capture can be enhanced by the discharge.

2. Orbital or external electron capture

\[ ^{58}\text{Co}(70.78\text{days}) + e^{-} \rightarrow ^{58}\text{Fe}(0.28\%) + \nu_e, \]  

with emission of energy \( Q_2 = 2.30408\text{MeV} \).

3. Double orbital or external electron capture

\[ ^{58}\text{Ni}(68.27\%) + 2e^{-} \rightarrow ^{58}\text{Fe}(0.28\%) + 2\nu_e, \]  

with emission of energy \( Q_2 = 1.92642\text{MeV} \) mostly by neutrinos.

The proposed cooperative mechanism of LENR in this case can be proved in an extremely simple way: presence of radioactive \(^{58}\text{Co} \) and enriched isotope of \(^{58}\text{Fe} \).

\( \otimes \) This mechanism can give possibilities to get a way of controlling the necessary isotopes and excess heat.

4.5 Neutrinoless Double Beta Decay

As we known [2], the physical roles of electron and neutrino for LENR in condensed matter has not been investigated in detail up to now despite the fact that weak processes in nuclei are well understood. The double beta decay is the rarest spontaneous nuclear transition, in which the nuclear charge changes by two units while the mass number remains the same. Such a case can occur for the isobaric triplet \((A(Z,N), A(Z \pm 1,N \mp 1), A(Z \pm 2,N \mp 2)), \) in which the middle isobar has a greater rest mass than the extreme ones, and the extremes are the nuclei with the even \( Z \) and \( N \). The usual beta-decay transferring a given nucleus into another via an intermediate nucleus is energetically forbidden.

The double beta decay in nuclei can proceed in different modes [16]:

\( \otimes \) The two neutrino decay mode 2\( \nu \beta \beta \)

\[ A(Z,N) \rightarrow A(Z + 2,N - 2) + 2e^{-} + 2\nu_e, \]  

which is allowed by the Standard Model of particle physics. The total kinetic energy of two emitted electrons present continuous spectra up to \( E_{\text{max}} \).

\( \otimes \) The neutrinoless mode 0\( \nu \beta \beta \)

\[ A(Z,N) \rightarrow A(Z + 2,N - 2) + 2e^{-}, \]  

which requires violation of a lepton number. The total kinetic energy of two emitted electrons is equal to \( E_{\text{max}} \).

Two neutrinos in the mode 2\( \nu \beta \beta \) carry out almost all emitted energies, which is useless for practical applications; therefore, this mode is not important for us. A fundamental question is: does the neutrinoless double beta decay exist or not (for the review of the history see [16]). The emerged energies in the neutrinoless 0\( \nu \beta \beta \) mode are easily detected for practical use but these
are the rarest spontaneous nuclear transitions ($T \approx 10^{18} - 10^{30}$ years). Is it possible to enhance the decay rate?

Above and in [1, 2, 3] we have discussed the cooperative and resonance synchronization enhancement mechanisms of LENR. Some of the low energy external fields can be used as triggers for starting and enhancing of exothermic LENR. It is natural to expect that in the case of beta-decay (capture) the external electron flux with high density, or a laser of high intensity, or any suitable external fields should play this role. Any external field shortening distances between protons in nuclei and electrons in atoms should enhance beta-decay (capture) or double-beta decay (capture).

There are a great number of experiments in Japan, Italy, Russia, US, India, China, Israel, and Canada in which cold transmutations and excess energy were measured (see http://www.lenr-canr.org).

It is very popular to use Ni, Pd, Pt and W as electrodes in the condensed matter discharge (breakdown, spark, arc, and explosion) experiments. Let us consider the case Pd electrodes. The difference of the rest mass of $m(^{110}Pd) - m(^{110}Cd) = 1.9989 MeV / c^2$; therefore, the external field can open the channel $^{110}_{46}Pd \rightarrow ^{110}_{48}Cd$ with $Q = 1.9989$. The experimental data [17] seem to confirm such expectations.

Therefore, expensive and time consuming double beta decay experiments can be performed in cheap and short-time experiments by using suitable external fields. This direction of research can open production of new elements (utilization of radioactive waste) and excess heat without ecological problem.

A careful analysis of the double beta decay shows that the $2e^-$ cluster can be responsible for the double beta decay. The difference between the rest mass $^{130}_{56}Ba$ and $^{130}_{52}Te$, which is equal to 92.55 keV, indicates the possibilities to capture the $4e^-$ cluster by $^{130}_{56}Ba$. It is a full analogy with the Iwamura reactions [18].

The lack of financial support and the ignorance from the whole physical society of LENR lead to catastrophes. The mechanism of shortening the runaway of the reactor at the Chernobyl Nuclear Power Plant and catastrophes induced by the HAARP (High Frequency Active Auroral Research Program) program is based on our postulated cooperative resonance synchronization mechanism. The same mechanism should be responsible for the ITER (International Experimental Fusion Reactor) explosion in future.

5 Conclusion

We proposed a new mechanism of LENR: cooperative processes in whole the system – nuclei + atoms + condensed matter can occur at a smaller threshold energies than the corresponding ones on free constituents. The cooperative processes can be induced and enhanced by low energy external fields. The excess heat is the emission of internal energy and transmutations at LENR are the result of redistribution of inner energy of the whole system.

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