Phenomenological model of collective Low Energy Nuclear Reactions (Transformation)

Introduction

After the famous press conference of Fleischmann and Pons, the term "cold fusion" ingrained behind the physical phenomenon of nuclear reactions at low temperatures. The opening idea of American scientists was that use of Pd cathode during electrolysis of "heavy" water could initiate nuclear fusion of deuterium (D + D) in the atomic lattice of Pd. But in the conclusions of the scientific article [1] published later, it was stated that the registered quantity of neutrons, tritium and gamma rays is by many orders of magnitude below the level that is needed to provide explanations for additional thermal power. It hereof follows that in the above experiment, the synthesis of deuterium is not a major nuclear process responsible for the allocation of additional thermal power. However, the term "synthesis" firmly entrenched in the minds of not only ordinary people, but of scientists engaged in LENR research as well.

The experimental conditions of creating a phenomenological model

Interest of the authors of this report to the LENR problem emerged in the late 90s of the last century in the study of multi-channel (8 channels were used) high current electric explosion of titanium foils in water. During the research, it was accidentally discovered that strong distortion of the original (natural) isotopic distribution was observed in the titanium powder formed by electric explosion. The relative Ti^{48}content in the powder was ~65% instead of natural 73.8% [2]. The measurements were duplicated on several types of mass spectrometers and the measurement results of isotopic Ti distortion coincided up to the inevitable experimental error ~1%. Moreover, with high accuracy degree no significant neutron flux or gamma radiation were registered during the experiments.

Analysis of numerous mass-spectrometric measurements showed that the parent nucleus Ti^{48} transgress not into a nuclei of other Ti isotopes or the nearest neighbors in the periodic table, which should have been observed in conventional nuclear reactions, but rather "dissolve" into a range of subsidiary chemical elements (from the lightest - to zinc) [2]. This process is clearly contrary to the traditional nuclear physics and initially seemed to be impossible.

The results of these experiments were independently confirmed by a similar setup at the Institute for Nuclear Research (Dubna). [3] Analysis of the experimental results showed that chemical elements are formed both lighter than iron (such as Al and Si) and heavier than iron. Energy reserve, which was used in the experiment, was not enough to initiate either one or the other process. The capacitor bank stored only 50 kJ per $10^{19\text{-}20}$ acts of nuclear reactions. Analyzing these results suggested the hypothesis that both synthesis and fission can occur at the same time. This can be represented as if the wave functions of the nuclei, for some reason, overlapped and an ensemble of the nearby nuclei "feel" themselves as a single kernel, in which protons and neutrons can be redistributed.

Some experiments on electric explosion were accompanied with a loud bang, and in these cases bright plasma glow occurred over the installation. In these experiments, a significant distortion of the isotopic Ti distribution was recorded. In the other experiments, the sound was quieter and no plasma "ball" or isotopic distortions were observed. Moreover, energy stored in the capacitor bank was the same, and even in "successful" experiments the installation was not destroyed. Consequently, the energy released by the nuclear processes in the order of magnitude matched that of the capacitor bank. Thus, the energy released in the observed nuclear reactions was significantly less than what could be expected in nuclear reactions as described in the traditional nuclear physics. This fact imposes stringent requirements on the enthalpy of hypothetical nuclear processes. Therefore, the question arises: is it possible to choose the combination of atoms in which the mass of the parent atom is different from that of the daughter atoms by the scale of chemical energy ≤ 1 keV (the mass of an electron is 0.5 MeV)?

If we assume a hypothetical possibility of collective nuclear reactions (according to some unknown new physical mechanism), it is necessary to require compliance with the fundamental conservation laws: energy, baryon, lepton and electric charges. A computer model was created that showed that if you allow the occurrence of weak nuclear processes and take Ti, O and H as parent nuclei, it is possible to choose the combination, where you can obtain daughter nuclei which are located in the periodic table before Zn inclusive. This was consistent with the experimental data. The model was called phenomenological, because there was no physical mechanism behind it, but only conservation laws. The phenomenological model suggested that if vanadium atoms are added to the parent atoms, it must form Fe^{57} isotope. This is a rare isotope and it is easy to identify. A corresponding experiment was conducted, and the result coincided with the predictions of the model, which was the argument in favor of the correctness of the path chosen.

The results have convinced us that there must be a new type of nuclear reactions, which we have called: transformation reactions (as opposed to the term "transmutation", which is used by all LENR researchers and which implies a shift of the nucleus of one chemical element into the nucleus of another chemical element). The introduction of the term "transformation", which was taken from the theory of groups, was intended to emphasize the fact that this is an entirely new class of nuclear reactions with a collective, rather than a two-partial character. It is usually considered that three- (or more) partial collisions are rare. However, collisions do not occur in transformation reactions. They are more similar to the exchange reactions rather than traditional nuclear reactions in which an intermediate nucleus occurs resulting from a collision and then breaks into the excited fragments. In nuclear physics, everyone is used to the fact that the greater the energy yield of the reaction channel, the more likely it occurs. Comparison of the experimental data against the results of calculations of the phenomenological model showed that all proceeds contrary in the transformation reactions, the smaller the difference in the masses ensembles of parent and daughter nuclei, the more likely the reaction to proceed through this channel.

In the electric explosion experiment majority of the daughter elements are formed in the isotopic distribution which is close to the natural one (with the exception of iron and antimony). Thus, the transformation reactions may be that very basic process that underlies the formation of matter, since it is an approximately constant isotopic distribution of chemical elements found in all visible regions of the universe allows us to assert about a unified mechanism of origin of matter (stars, planets, meteorites).

Phenomenological model

One of the problems of the traditional nuclear physics is calculating the energy balance from the known reaction products. Well-known characteristics of nuclei are used for its solution: the nuclear binding energy, nuclear mass, the mass defect of the nucleus. The task faced by phenomenological model is somewhat different and it is in finding the unknown sets of daughter nuclei close in energy to the original set of cores. The above characteristics are not convenient for the solution of that problem. First, these characteristics do not take into account the laws of conservation of electric and baryon charge (number of nucleons) - it is necessary to simultaneously monitor these conservation laws in the calculation of the energy of nuclear reactions. Second, these characteristics were chosen with rather inconvenient zero levels: for example, the binding energy is equal to zero for both proton and neutron - and this is quite different objects; and the mass defect of the nucleus is zero in C^{12} nucleus, which does not reflect physical reality.

The basis for constructing a phenomenological model of collective transformation of nuclei is a new energy rule that allows convenient, adequate and unique evaluation of the sets (groups, ensembles) of cores. This is of the norm of nuclei set $\{X_i\}$:

$$\|\{X_i\}\| = \sum_{i}^{N} \|X_i\| ,$$

$$\|X_i\| = W_i + (Z_i - A_i) \cdot (m_n - m_H) ,$$

where W_i, Z_i and A_i- the binding energy , the charge (in units of the electron charge) and the atomic mass of the nucleus X_i; m_n and m_H - the mass of the neutron and the neutral hydrogen atom:

$m_n - m_H \approx 782.3$ keV - the energy of β-decay of a neutron into a bound state of an electron (i.e. β-decay with the formation of neutral hydrogen atom). Introduced norm automatically takes into account the preservation of the electric and baryon charges during nuclear transformations and equal to zero on the set, consisting of neutral hydrogen atoms.

If we consider the traditional nuclear reactions (nuclear decay, fission, fusion)

$$\sum_{input} X_i \to \sum_{fin} X_j ,$$

then the energy released in a nuclear reaction is equal to the difference between the original atomic masses of elements and the reaction products:

$$Q = \sum_{input} M_i - \sum_{fin} M_j .$$

Let us proceed from the masses of neutral atoms *M* to the nuclear binding energy *W*:

$$M_i = (A_i - Z_i)m_n + Z_i\left(m_p + m_e\right) - W_i ,$$

where m_p and m_e - masses of a proton and an electron. It should be remembered that, based on the definition of the nuclear binding energy, it follows that it is not the nucleons binding energy in the nucleus, but the sum of binding energy of the nucleons in the nucleus and the electrons in the neutral atom [4]. I.e. the binding energy W - is the energy required for the separation of neutral atom into its constituent protons, neutrons and electrons of the atomic shell. The fact that this is precisely the total binding energy of nucleus and the atomic electrons, follows, for example, from the measuring method of the binding energy in the β-decay of nuclei - to determine the binding energy (which are indicated in the tables of physical quantities) the decays of neutral atoms in the neutral atoms are investigated. That is why the β-decay of fully ionized nuclei has a completely different energy of β-decay and a different β-decay period, compared with the decay of neutral atoms [5]. Of course, in most cases, the energy of the electrons in an atom can be neglected in comparison with the binding energy of the nucleons in the nucleus, when we calculate the energy released in the traditional nuclear reactions. However, the energy of the electrons in the atom cannot be neglected in the calculation of the energy released in the collective nuclear transformation.

The suggested nuclei norm $\|X_i\|$ is the energy required for the separation of neutral atoms to neutral hydrogen atoms and neutrons, followed by the decay of neutrons in the neutral hydrogen atoms. This means that the zero of this norm is selected for the set of nuclei consisting of neutral hydrogen atoms. To determine the energy released (or absorbed) by nuclear transformation of some initial set of nuclei in the final set, it is necessary to subtract the norm of the initial set from norm of a final set. You do not need to follow the laws of conservation of electric and baryon charge - they are included in norm and are included in the calculation automatically.

We believe that the process of collective nuclear transformation proceeds in the "delicate" way in which nuclear transformations occur between multiple nuclei with close total energies, that is the process goes through the resonance path. The use of this norm in the phenomenological model allows to quickly find the ensembles of nuclei close in value of the total energy. When searching for the closest sets, only nuclei other than hydrogen should be taken into account. Unlike the solutions of traditional problems of nuclear physics in which the energy of processes is calculated with well-known products of the reaction, the problem of the phenomenological model consists in finding the unknown sets of nuclei close in energy to the original set of cores. Obviously, the use of the proposed norm, which take into account the laws of conservation of baryon and electric charges, greatly facilitates the task.

Rossi Experiments

We suggest to consider the reaction of the proton capture by nucleus Li^7 [6] in an attempt to explain the observed isotopic distortion of Li in the Rossi experiments:

$$Li^7 + p \rightarrow Be^8 + 17.255\ MeV \rightarrow 2He^4 + 17.347\ MeV\ .$$

From our point of view, it does not explain the process of transformation, which leads to a distortion of the isotopic distribution of Li: first, a lot of energy produced during this reaction, and secondly there is a similar reaction for Li^6

$$Li^6 + p \rightarrow He^4 + He^3 + 4\ MeV$$

If we assume that the transformation proceed through the channels with small energies, then the analysis of the closest, by the phenomenological model, sets can explain pre-emptive disappearance of the Li^7 nuclei compared to Li^6 nuclei. At the same time the results of the calculation shows that the hydrogen atoms are absorbed in three partial transformation process:

$$Li^7 + 2H \rightarrow Li^6 + He^3 + 0.47\ MeV$$

Also, the phenomenological model implies that Li^7 better combines with Ni rather than Li^6, for example:

$$Li^7 + Ni^{60} + 2H \rightarrow N^{15} + Mg^{25} + Si^{29} + 0.004\ MeV$$

The authors of this paper have little doubt in the fact that the "cold fusion" phenomenon does not exist. At the heart of the processes observed in the LENR experiments, lie low-energy transformations which bear a collective character.

References

1. M. Fleischmann, S. Pons and M. Hawkins, J. Electroanal. Chem. **261**, 301 (1989).
2. L. I. Urutskoev, V. I. Liksonov, V. G. Tsinoev, *Ann. Fond. L. de Broglie* **27**, 701 (2002).
3. V. D. Kunznetsov, G. V. Mishinsky, F. M. Penkov, V. I. Arbuzov, V. I. Zhemenik, *Ann. Fond. L. de Broglie* **28**, 173 (2003).
4. L. I. Urutskoev, D. V. Filippov, *Physics–Uspekhi* **47**, 1257 (2004).
5. F. Bosch, T. Faestermann, J. Friese, et al., *Phys. Rev. Lett.* **77**, 5190 (1996)
6. N. Cook, A. Rossi, On the Nuclear Mechanisms Underlying the Heat Production by the E-Cat, http://arxiv.org/ftp/arxiv/papers/1504/1504.01261.pdf