A new experimental demonstration of low energy nuclear reactions

ABSTRACT

This talk discusses the recent findings of the Tohoku group related to low energy nuclear reactions (LENR) or "cold fusion" as it was called earlier. Unlike in electrolysis experiments, the target is solid consisting of nanolayears of Ni and Cu plus Ni in bulk. The experiment involves heating and heat production, which can be almost 20 per cent of the incoming power and cannot be explained chemically. The reported initial and final state concentrations of Ni^-, Cu^-, C^-, O^-, and H^- in the target suggest that melting has occurred.

The emergence of ions should be understood. O^- ions are detected only in the final situation. The mystery is how the oxygen, present in the H_2 pressurized chamber, manages to get to the target.

The TGD based model is a refinement of the earlier model. The reversal $2H_2+O_2\rightarrow 2H_2O$ of water electrolysis transforms the situation to that appearing in electrolysis and Pollack effect for water and its generalization for metal hydrides would be the basic mechanism producing dark nuclei as dark proton sequences, which transform spontaneously to ordinary nuclei.

This talk can be found at my homepage as a powerpoint file at https://tgdtheory.fi/tgdmaterials/LENRpp.pptx and as pdf file at https://tgdtheory.fi/tgdmaterials/LENRpdf.pdf .

Experimental findings and their interpretation

There are highly interesting new experimental results related to low energy nuclear reactions (LENR) discussed in a popular article published in New Energy Times (see this). The article gives a rather detailed view of the findings of the Tohoku group. There is also a research article by Iwamura et al with the title "Anomalous heat generation that cannot be explained by known chemical reactions produced by nano-structured multilayer metal composites and hydrogen gas" published in Japanese Journal of Applied Physics (see this).

Note that LENR replaces the earlier term "cold fusion", which became a synonym for pseudoscience since standard nuclear physics does not allow these effects. In practice, the effects studied are however the same.

The basic problem is how to overcome the Coulomb wall preventing ordinary fusion. LENR often involves Widom-Larsen theory (see this) based on the assumption that the fundamental step in the process is not strong interaction but weak interaction of a heavy electron with a proton. This would produce a neutron, which is very nearly at rest and is able to get near the target nucleus with a large enough probability, necessary to compensate the weakness of the weak interaction.

The assumptions that the electron has a large effective mass, produced by the minimal coupling to the fluctuating classical electromagnetic field, prevailing near negatively charged metallic hydrid surfaces, and that neutron is very nearly at rest, can be challenged. The understanding of detailed mechanisms producing the observed nuclear transmutations is not understood in the model.

1. The experiments of the Tohoku group

- The target consists of alternating layers consisting of 6 Cu layers of thickness 2 nm and 6 Ni layers of thickness 14 nm. The thickness of this part is 100 nm. Below this layer structure is a bulk consisting of Ni. The thickness of the Ni bulk is 10^5 nm. The temperature of the hydrogen gas is varied during the experiment in the range 610 - 925 degrees Celsius. This temperature range is below the melting temperatures of Cu (1085 C) and Ni (1455 C).

- The target is in a chamber, pressurized by feeding hydrogen gas, which is slowly adsorbed by the target. Typically this takes 16 hours. In the second phase, when the hydrogen is fully adsorbed, air is evacuated from the chamber and heaters are switched on. During this phase excess heat is produced. For instance, in the first cycle the heating power was 19 W and the excess heat was 3.2 W and lasted for about 11 hours. At the end of the second cycle heat is turned off and the cycle is restarted. The experiment ran for a total of 166 hours, the input electric energy was 4.8 MJ and the net thermal energy output was .76 MJ.

- The figure of the popular article (https://newenergytimes.com/v2/news/2024/2024Tohoku/2024Tohoku-Fig7.png) summarizes the temporal progress of the experiment and pressures and temperatures involved. Pressures are below 250 Pa: note that one atmosphere corresponds to 101325 Pa.

- The energy production is about 10^9 Joule per gram of hydrogen fuel. A rough estimate gives thermal energy production of about 10 keV per hydrogen atom. Note that the thermal energy associated with the highest temperature used (roughly 1200 K) is about .12 eV. In hot nuclear fusion the power gain is roughly 300 times higher and about 3 MeV per nucleon. The ratio of the power gain to the input power is below 16 per cent typically in a given phase of the experiment.

The Tohoku group has looked for changes in the abundances of elements and for unusual isotopic ratios after the experiments. Iwamura reports that they have seen many unusual accumulations.

- **Second figure (https://newenergytimes.com/v2/news/2024/2024Tohoku/2024Tohoku-Fig19.jpg) represents the the depth profiles in the range 0-250 nm for the abundances of Ni^-, Cu^-, C^-, O^-, Si^- and H^- ions for the initial and final situations for an experiment in which excess heat of 9 W was generated. The original layered structure has smoothed out, which suggests that melting has occurred. This cannot be due to the feed of the heat energy. The melting of Ni requires a temperature above 1455 C.**

- **Earlier experiments were carried out in the adsorption phase. The recent experiments were performed in the desorption phase and the heat production was higher. The proposal is that the fact that the desorption is a faster process than the adsorption could somehow explain this.**

- **The most prevalent is an unusually high percentage of the oxygen showing up below the surface of the multilayer composite, within the outer areas of the bulk. Pre-experiment analysis for the presence of oxygen concentration, after fabrication of the multilayer composite, has indicated a concentration of 0.5 to a few percent down to 1,000 nm from the top surface. The Tohoku group has observed many accumulations of O^- in post-experimental analyses exceeding 50 percent in specific areas.**

- **Iwamura says that once the multilayer is fabricated, there is no way for atmospheric oxygen to leak below the top surface, at least beyond the first few nanometers. As a cross-check, researchers looked for nitrogen (which would suggest contamination from the atmosphere) but they detected no nitrogen in the samples.**

Theoretical models

1. Widom-Larsen theory

Krivit has written a 3-part book "Hacking the atom: Explorations in Nuclear Research" about the history of cold fusion/LENR. I have written an article inspired by this book about LENR in the TGD framework. The basic challenge is to overcome the Coulomb wall somehow.

The basic idea of Widom-Larsen theory is as follows.

- First, heavy surface electrons are created by the fluctuations of classical electromagnetic fields near the negatively charged surfaces of metal hydrides serving also as catalysts. The effective mass comes from the minimal coupling to the fluctuating classical electromagnetic field.
- The heavy electron binds with a proton and by weak interaction gives rise to an ultra-low momentum neutron and neutrino. The heaviness of the surface electron implies that the kinetic tunnelling barrier due to Uncertainty Principle is very low and allows electron and proton get very near to each other so that the weak transition $p + e \rightarrow n + \nu$ can occur.
- Neutron has no Coulomb barrier and has very low momentum so that it can be absorbed by a target nucleus at a high rate. The low momentum compensates for the extreme weakness of the weak interaction.

There are objections against the idea.

- The difference of proton and neutron masses is $m_n - m_p = 2.5m_e$. The final state neutron produced in $p + e \to n + \nu$ must be almost at rest. This requries fine tuning. Extremely strong em fields are required.

- One can argue that at the fundamental level ordinary kinematics, instead of the effective kinematics based on minimal coupling, should be used. The straight forward conclusion would be that in the standard kinematics the energy of an electron must be $2.5m_e$ so it would be relativistic.

- A further criticism relates to the heaviness of the surface electron. There are very tight constraints on the value of the effective mass. I did not find from the web any support for heavy electrons in Cu and Ni (in the standard condensed matter sense). Wikipedia article (see this) and web search suggest that they quite generally involve f electrons and they are absent in Cu and Ni.

2. TGD based model very briefly

Can one generalize the TGD based model derived to explain the electrolysis based "cold fusion”? The findings indeed allow to sharpen this model, based on generation of dark nuclei as dark proton sequences with binding energies in few keV range instead of MeV range. Pollack effect is in a key role. One can try to understand what happens by starting from 3 mysteries.

- The final state contains Ni^-, Cu^-, C^-, Si^-, O^-, and H^- ions. What causes their negative charge? In particular, the final state target contains O^- ions although there is no oxygen present in the target in the initial state! A further mystery is that the Pollack effect producing HO^- requires water. Where could the water come from?

- Could O_2 and H_2 molecules present in the chamber in the initial state give rise to oxygen ions in the final state? Could the spontaneously occurring $2H_2+O_2 \rightarrow 2H_2O$ as reversal of the electrolysis of water in the H_2 pressurized chamber, liberating energy of about 4.8 eV , generate the water, which leaks to the target volume? Note that the reverse of this reaction occurs in photosynthesis. If so, the Pollack effect, could take place for the water. It would transform ordinary protons to dark protons and would generate oxygen ions in a negatively charged exclusion zone.

- The generalization of Pollack effect for metal hydrids could produce the other ions in the initial and final states. It could occur spontaneously. The reversal of metallic Pollack effect could generate photons giving rise to Pollack effect for water.

- Spontaneous transformation of dark nuclei to ordinary ones would liberate essentially all the ordinary nuclear binding energy. Although the transformation to ordinary nuclei is not needed to explain the heat production, it is necessary to explain the nuclear transmutations. The dark nuclei could be rather stable and the X-ray counterpart for the emission of gamma rays could explain the heating. The absence of gamma rays in "cold fusion" is the killer objection against it. Gamma rays would be replaced by X rays in 1-10 keV range, which is also the average thermal energy produced per hydrogen.

- In the transformation to ordinary nuclei, practically all ordinary nuclear binding energy is liberated. This could create the reported craters at the surface of the target in electrolysis experiments. Dark and ordinary nuclei could also leave the system.

- How to understand the poor replicability of ”cold fusion”? Pollack effect occurs at quantum criticality as a phase transition. Quantum criticality would make dark fusion difficult to realize. It would occur only for very special values of control parameters. Also, the dark nuclei or their decay products could be lost, if they end up to flux tubes leading from the system to the external world. The long lifetime of dark nuclei against transformation to ordinary nuclei could be also important.

A brief summary of some basic ideas of TGD

1. The new view of space-time and fields provided by TGD

- Geometric vision leads to a new view of space-time as a 4-D surface X^4 in "hyper-space" $H = M^4 \times CP_2$ and implies that space-time is topologically non-trivial in all scales. Space-time surfaces have finite size and their boundaries correspond to the boundaries of physical objects.

- Space-time surfaces can be seen as orbits of particles as 3-D surfaces, which by 4-D general coordinate invariance must satisfy holography and are analogous to Bohr orbits of particles. The generalization of point-like particle to 3-D surface brings in size and shape. TGD thus generalizes string models.

- The new view of classical fields. The fields associated with physical systems correspond to finite space-time sheets: one can talk about field body or about magnetic/electric body (MB/EB). Also field bodies have size, shape. They have flux tubes and flux sheets as body parts.

2. TGD predicts two kinds of magnetic flux tubes.

- **Monopoles flux tubes, have a closed cross section and are closed. Maxwellian half-monopole flux tubes have boundary and need not be closed. The latter could be important in the temperature region above the transition temperature in the case of high Tc superconductors. Monopole flux tubes are in a key role in the TGD based quantum biology.**

- **There are magnetic and electric flux tubes. Electric flux tube as a small deformation of the magnetic flux tube. Two kinds of electric flux tubes: closed monopole flux tubes and the Maxwellian ones.**

3. Hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter at field bodies

- **Predicted by the number theoretic vision of TGD.**

- **The larger the value of h_{eff}, the longer the quantum coherence scales are and field bodies can be macroscopic quantum systems. Their algebraic complexity also increases with h_{eff} which is essentially the dimension of algebraic extension of rationals characterizing the space-time region in question. Field body serves as a "boss" of the system to which it is associated. Field body induces the coherence of the ordinary biomatter.**

- **TGD predicts that classical gravitational fields of the Sun, Earth and other planets are responsible for very large values of effective Planck constant $h_{eff} = h_{gr}$ for ordinary particles located at the gravitational monopole flux tubes. This proposal generalizes for electric fields with effective Planck constant $h_{eff} = h_{em}$. Examples: electric fields of DNA, cell, of ionospheres of the Earth and Sun, and also of large capacitor-like systems, EZ(!). Electric monopole flux tubes for these systems could carry dark electrons with $h_{eff} = h_{em}$.**

4. Pollack effect

The increase h_{eff} implies increase of complexity and intelligence. It requires energy having interpretation as metabolic energy.

- **In the Pollack effect water is irradiated with electromagnetic radiation at visible and IR frequencies. This induces the transfer of every 4:th proton somewhere and generation of exclusion zone (EZ), which has the stoichiometry $H_{1.5}O$, forms a layer-like structure formed by 2-D hexagonal lattices. EZs exclude various inpurities, which suggests a kind of time reversed diffusion. The proposal is that the protons go to the magnetic body of the system and become dark protons with a very large value of h_{eff}.**

- **Pollack effect generalizes. The energy needed to increase h_{eff} can come from the formation of molecules as bound states of atoms and this could be essential for the formation of biomolecules and would mean a new kind of chemistry. In particular, for metal hydrids Pollack effect could occur spontaneously.**

- **Also electrons can be transferred to dark electrons at magnetic or electric bodies and in the case of capacitor-like systems electrostatic energy could make possible the increase of h_{eff}. EZ would could be such a system. Pollack effect would induce formation of dark electrons. Do the dark protons and electrons reside at separate monopole flux tubes?**

TGD inspired model of nuclear transmutations

1. Basic elements of the model of ”cold fusion” as dark fusion

TGD suggests dark fusion (see this and this) as the mechanism of "cold fusion".

- **The model relies on the hierarchy of Planck constants $h_{eff} = n \times h$ (see this , this , this and this) labelling the phases of ordinary matter emerging at quantum criticality and behaving like dark matter. h_{eff} implies scaled up Compton lengths and other quantum lengths making possible quantum coherence at longer scales than usually. The hierarchy of Planck constants $h_{eff} = n \times h$ has now a rather strong theoretical basis and reduces to number theory (see this). Quantum criticality is essential and could help to explain the difficulties to replicate the effect.**

- **Pollack effect serves as the mechanism of dark fusion. Irradiation of water in the presence of gel phase generates negatively charged exclusion zones (EZs) inside which water has the stoichiometry $H_{1.5}O$. Every 4:th proton must go somewhere and the TGD inspired proposal is that they go to dark protons at the monopole flux tubes of the magnetic body associated with the water. These dark protons give rise to dark nuclei with binding energies in 1-10 keV range. These in turn would transform to ordinary nuclei.**

- **Gravitational flux tubes of the Earth or Sun, with gravitational Compton length Λ_{gr} equal to one half of Schwartscild radius $r_s = 2GM$, is one option. For the Earth one has $\Lambda_{gr,E} =$ .5 cm. For the Sun one has with $\Lambda_{gr,S} = R_E/2$, where R_E is the radius of Earth. There are also options characterized by much smaller effective Planck constant. In particular, negatively charged systems involve magnetic body characterized by electric Planck constant proportional to the total charge of the system (DNA, cell, and Earth are basic examples).**

2. Dark fusion

- Dark fusion would generate dark nuclear strings as dark proton sequences at monopole flux tubes. At the flux tubes protons would have $h_{eff} = n \times h$ and form dark nuclear strings. Also ordinary nuclei are predicted to be string like entities (see this).

- What about dark nuclei with neutrons? Spontaneous beta decays of protons could take place inside dark nuclei just as they occur inside ordinary nuclei. If the weak interactions are as strong as electromagnetic interactions (large value of h_{eff}), dark nuclei could rapidly transform to stable dark nuclei containing neutrons.

- If the transformation to ordinary nuclei occurs slowly, the isotope ratios of dark nuclei could stabilize. If the dark stability means the same as the ordinary stability, also the isotope ratios of the produced ordinary nuclei would be same as in Nature. There are some indications for this.

- Dark nucleosynthesis could serve as the mechanism of nucleosynthesis outside stellar interiors. This mechanism could allow at least the generation of nuclei heavier than Fe, not possible inside stars. Supernova explosions would not be needed. Also the formation of protostars could begin with dark fusion, which gradually heats up the system so that the ordinary fusion is eventually ignited. What about stellar interiors?

- The simplest possibility is that the dark protons are just added to the growing dark nuclear string. Besides protons, also deuterons and even heavier nuclei, can end up to the magnetic flux tubes. They would however preserve their size and only the distances between them would be scaled to about electron Compton length on the basis of the data provided by Holmlid's experiments (see this and this) .

3. The origin of negative ions in Tohoku experiments

The presence of ions Ni^-, Cu^-, C^-, Si^-, O^-, H^- ions in the target serves as a guideline. In TGD, Pollack effect generating EZs, would serve as the ionization mechanism producing HO^- ions.

- What is remarkable is the appearance of O^-. The Coulomb wall makes it very implausible that the creation of an ordinary alpha particle in LENR could induce the transmutation of C to O. Could the oxygen be produced by dark fusion? It is difficult to see why oxygen should have such a preferred role as a reaction product in dark fusion favouring light nuclei?

- Could the oxygen enter the target during the first phase when the pressurized hydrogen gas is present together with air, as the statement that air was evacuated after the first stage, suggests? Iwamura has stated that nitrogen N, also present in air, is not detected in the target so that the leakage of O to the target looks implausible. Could a leakage of oxygen to the target rely on a less direct mechanism?

- Oxygen and hydrogen appear as molecules. O_2 *resp.* H_2 has a binding energy of 5.912 eV *resp.* 4.51 eV. Therefore $2H_2 + O_2 \rightarrow 2H_2O$ as reversal of water hydrolysis could occur during the pressurization phase. The energy liberated in this reaction is estimated to be about 4.88 eV (see this). In the "cold fusion" based on electrolysis, the water would be present from the beginning but now it would be generated by the reversal of electrolysis of water and its leakage to the target.

- Water plays a key role in the Pollack effect interpreted as a formation of dark proton sequences. The generalized Pollack effect could generate also other negatively charged ions besides O^-. Ni^-, Cu^-, C^-, Si^-, O^-, H^- ions would serve as a signature of these regions. For metal hydrides Pollack effect could take place spontaneously.

4. The role of the catalyst in the process

In Pollack effect, the presence of gel phase, bounding the water and acting as a catalyst, makes possible Pollack effect near the boundary, where negatively charged EZs are formed. In electrolysis experiments, the target is also a catalyst. Also metal hydrides are catalysts.

- **In the ordinary Pollack effect, the initial and final states of the reaction $OH \rightarrow O^- + p$ have almost the same energies: the energy difference is above IR energy of about .3 eV corresponding to physiological temperature 300 K. Overcoming the energy barrier requires energy of order of bonding energy of OH bonds about 5 eV. The gel phase acts as a bio-catalyst helping to overcome the energy wall preventing $OH \rightarrow O^- + p$.**

- **The reversal $2H_2 + O_2 \rightarrow 2H_2O$ of electrolysis of water could produce an excitation of H_2O with energy near the energy making possible to overcome the potential barrier for the $H_2O \rightarrow HO^- + p$. No catalyst would be needed. The temperatures used correspond to a thermal photon energy scale between .22-.33 eV.**

- **The transformation of ionized metal hydrides to neutral form by the reverse Pollack effect could liberate energy as a photon inducing the Pollack effect for the excitations of H_2O molecules.**

- **For the generalized Pollack effect, O is replaced by the metal of the metal hydride. In the generalized Pollack effect, metal-hydrogen bond would split to metal ion and dark p and produce ion $I^- \in \{Ni^-, Cu^-, C^-, O^-, Si^-, H^-\}$.**

5. Pollack effect and zero energy ontology (ZEO)

One can imagine several ZEO based models for the Pollack effect based on the TGD view of quantum tunnelling as two "big" state function reductions (BSFRs), each changing the arrow of geometric time. The following is just one possible guess.

- Assume that the presence of the catalyst C makes the system ***catalyst + water molecule*** quantum critical against splitting $OH \rightarrow O^- + p$, where OH belongs to water molecule and p is dark proton at the monopole flux tube. The system would be in a superposition of states $C(E) + H_2O(E_w)$ and $C(E - \Delta E) + H_2O(E_w + \Delta E)$ so that the water molecule and catalyst are entangled. One can speak of energy entanglement. The energy $E_w + E$ of H_2O in the critical state is slightly below the top of the potential barrier preventing the splitting to $HO^- + p$ consisting of water ion and dark proton.

- The absorption of the Pollack photon γ by water molecule makes this transition energetically possible. In the ZEO based view of quantum tunnelling, the decay could be induced by the first BSFR generating a time reversed state as a superposition of states $C(E - \Delta E) + H_2O(E_1)$ and the state $C(E - \Delta E) + (HO^- + p)(E_1)$.$E_1 = E_w + \Delta E + E(\gamma)$ in which Pollack effect has occurred.

- In the second BSFR, the state $C(E - \Delta E) + (HO^- + p)(E_1)$ in which pollack effect has occurred, can be selected.

- It evolves in the standard time direction and decays spontaneously by emitting a virtual photon with energy ΔE absorbed by C so that the state $C(E) + (HO^- + p)(E_w + E(\gamma))$ emerges. The dark proton receives an energy compensating the gravitational binding energy, which at maximum is of order 1 eV. .3 eV is the energy scale for the difference of the bonding energy of OH bond and binding energy of e^- in O^- ion (see this).

References

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