Exploration

A New Experiment Demonstrating the Occurrence of Low Energy Nuclear Reactions

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Abstract

This article discusses the recent findings of the Tohoku group related to low energy nuclear fusion (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. The reported initial and final state concentrations of negative Ni, Cu, C, O, and H ions in the target suggest that melting has occurred. The emergence of ions should be understood. O^- ions are detected only in the final state. The mystery is how the oxygen, present in the H_2 pressurized chamber, manages to get to the target. The TGD based model refines the earlier model applying to electrolysis based (ordinary) "cold fusion". The reversal $2H_2 + O_2 \rightarrow 2H_2O$ of water electrolysis transforms the situation to that appearing in ordinary "cold fusion". If water molecules are created in an excited state near the top of the potential barrier preventing Pollack effect, no catalyst is needed for Pollack effect as in the biological situation (, where gel phase is needed). Pollack effect could occur spontaneously for metal hydrides and its reversal could generate photons inducing the Pollack effect for water, producing oxygen ions. The dark protons generated in the Pollack effect would produce dark nuclei as dark proton strings and these would transform spontaneously to ordinary nuclei giving rise to nuclear transmutations and liberating almost all ordinary nuclear binding energy. If the rate of this process is slow, it does not contribute considerably to the heating. Nuclear gamma rays are replaced with X rays for dark nuclei so that the basic objection against "cold fusion" is overcome. The quantum criticality of the phase transition inducing Pollack effect explains why "cold fusion" experiments are difficult to replicate.

1 Introduction

I learned of highly interesting new experimental results related to low energy nuclear reactions (LENR) from a popular article published in New Energy Times (see this) giving 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 [2].

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 [7, 9, 8] (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.

The assumptions that the electron has a large effective mass, produced by the minimal coupling to the fluctuating classical electromagnetic fields prevailing near negatively charged metallic hydride 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.

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1.1 Experiments of the Tohoku group

Consider first the experimental arrangement and results.

1. 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).

2. 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.

3. The figure of the popular article (see this) 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 1000 K) is about .1 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.

1. Second figure (see this) 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.

2. The most prevalent is an unusually high percentage of the element 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 oxygen in post-experimental analyses exceeding 50 % 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.

1.2 Theoretical models

Krivit has written a 3-part book "Hacking the atom: Explorations in Nuclear Research " about the history of cold fusion/LENR [4, 5, 6]. I have written an article inspired by this book [23]. Krivit sees the Widom-Larsen theory [7, 9, 8] (see this) as the most promising model of LENR.

1.2.1 Widom-Larsen theory

The basic idea of Widom-Larsen theory (see this) is as follows.

1. First, a heavy surface electrons are created by the fluctuations of classical electromagnetic near the negatively charged surfaces of hydride metals. The effective mass comes from the minimal coupling to the fluctuating classical electromagnetic field.

2. 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+ν can occur.

3. 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.

1. The difference of proton and neutron masses is $m_n - m_p = 2.5m_e$. The final state neutron produced in p+e $\rightarrow$ n+ν is almost at rest. 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.

2. Second 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. Wikipedia article (see this) and web search suggest that they quite generally involve f electrons and they are absent in Cu and Ni.

If one assumes that the Widom-Larsen mechanism is a correct way to overcome the Coulomb wall, it is natural to look what kinds of stable end products the initials states n + Ni and n+ Cu, made possible by the Widom-Larsen mechanism, could yield.

1. The most abundant isotope of Ni has charge and mass number $(Z, A = Z + N) = (28, 59)$ (see this). Ni has other stable isotopes with $A \in \{58, 60, 61, 62, 64\}$. The most abundant isotope of Cu has $(Z, A) = (29, 63)$ (see this) and stable isotopes have $A \in \{63, 65\}$.

   For Ni stable isotopes with $A \geq 60$ could transform to stable isotopes with single neutron absorption. For Cu the absorption of two neutrons would be required.

2. One can also look more general reactions in which the final state neutron transforms to proton by beta decay n$\rightarrow$ p+ν. This mechanism could lead from stable Ni isotope (28,62)*resp.* (28,64) to stable Cu isotope (29,63) *resp.* (29,65).

   For Cu this mechanism could lead from $(Z, A) \in (29, \{63, 65\})$ to Zn isotope $(Z, A) \in (30, \{64, 66\}))$. This could be followed by alpha decay to Ni isotope $(Z, A) \in (28, \{60, 62\})$. Second alpha decay would lead to Fe with $[Z, A] \int (26, \{58, 60\})$. Iron has 4 stable isotopes with $A \in \{54, 56, 57, 58\}$. ^{60}Fe is a radionuclide with half life of 2.6 million years decaying to ^{60}Ni.

I also found a second model involving heavy electrons but no weak interactions (see this). Heavy electrons would catalyze nuclear transmutations. There would be three systems involved: electron, proton and nucleus. There would be no formation of an ultralow energy neutron. An electron would form a bound state with a proton with nuclear size. Although Coulomb attraction is present, the Uncertainty Principle would prevent the tunnelling of ordinary electrons to a nuclear distance. It is argued that a heavy electron has a much smaller quantum size and can tunnel to this distance. After this, the electron is kicked out of the system and by energy conservation its energy is compensated by a generation of binding energy between proton and nucleus so that heavier nucleus is formed. The same objection applies to both the Widom-Larsen model and this model.

1.2.2 TGD based model very briefly

What about the TGD based model derived to explain the electrolysis based "cold fusion" [11]? The findings indeed allow to sharpen the TGD based model for "cold fusion" based on generation of dark nuclei as dark proton sequences with binding energies in keV range instead of MeV range. One can understand what happens by starting from 3 mysteries.

1. The final state contains negatively charged Ni^-, Cu^-, C^-, S^-i, 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!

2. A further mystery is that the Pollack effect requires water. Where could the water come from?

   Could O_2 and H_2 molecules, present in the chamber in the initial state, somehow give rise to oxygen ions in the final state? Could the spontaneously occurring $2H_2+O_2 \rightarrow 2H_2O$ as a reversal of water hydrolysis (see this)in the H_2 pressurized chamber, liberating energy of about 4.5 eV, generate water, which would leak to the target volume.

3. Could the Pollack effect take place for the water? Pollack effect for water could transform ordinary protons to dark protons and generate a negatively charged exclusion zone involving O^- ions appearing only in the final state. The situation would effectively reduce to that in systems involving electrolyte studied in the original "cold fusion" experiments. Could the water ions created in the above reaction be in an excited state near the threshold for the occurrence of Pollack effect so that no catalyst as a counterpart of the gel phase would be needed.

   The Ni^-, Cu^-, C^-, S^-i, and H^- ions appear also in the initial state. The generalization of Pollack effect to metal hydrides could occur spontaneously and generate these ions already in the initial state.

4. The spontaneous transformation of dark nuclei to ordinary ones would liberate essentially all the ordinary nuclear binding energy if the binding energy scale of dark nuclei is in a few keV range. It is of course not obvious whether the transformation to ordinary nuclei is needed to explain the heat production: it is however necessary to explain the nuclear transmutations, which are not discussed in the article of Tohoku group. The resulting 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 is the killer objection against "cold fusion" based on standard nuclear physics. In TGD gamma rays would be replaced by X rays in keV range, which is also the average thermal energy produced per hydrogen atom.

5. 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.

2 TGD inspired models of "cold fusion"

TGD suggests dark fusion [23, 26] as the mechanism of "cold fusion". One can consider two models explaining these phenomena in the TGD Universe. Both models rely on the hierarchy of Planck constants $h_{eff} = n \times h$ [12, 13, 14, 15, 16] explaining dark matter as ordinary matter in $h_{eff} = n \times h$ phases emerging at quantum criticality. h_{eff} implies scaled up Compton lengths and other quantal lengths making possible quantum coherence at longer scales than usual.

The hierarchy of Planck constants $h_{eff} = n \times h$ has now a rather strong theoretical basis and reduces to number theory [24, 25]. Quantum criticality would be essential for the phenomenon and could explain the critical doping fraction for cathode by D nuclei. Quantum criticality could help to explain the difficulties to replicate the effect.

2.1 Simple modification of WL does not work

The first model is a modification of WL and relies on dark variants of weak interactions. In this case LENR would be an appropriate term.

1. Concerning the rate of the weak process $e + p \rightarrow n + \nu$ the situation changes if h_{eff} is large enough and rather large values are indeed predicted. h_{eff} could be large also for weak gauge bosons in the situation considered. Below their Compton length weak bosons are effectively massless and this scale would scale up by factor $n = h_{eff}/h$ to almost atomic scale. This would make weak interactions as strong as electromagnetic interactions and long ranged below the Compton length and the transformation of proton to neutron would be a fast process. After that a nuclear reaction sequence initiated by neutrons would take place as in WL. There is no need to assume that neutrons are ultraslow but electron mass remains the problem. Note that also proton mass could be higher than normal perhaps due to Coulomb interactions.

2. As such this model does not solve the problem related to the too small electron mass. Nor does it solve the problem posed by gamma ray production.

2.2 The model of "cold fusion" as dark fusion based on Pollack effect

At this moment, the identification of "cold fusion" as dark fusion looks the most promising TGD based view of "cold fusion".

2.2.1 Basic elements of the model of cold fusion as dark fusion

TGD suggests dark fusion [23, 26] as the mechanism of "cold fusion".

1. The model relies on the hierarchy of Planck constants [12, 14, 14, 15], labelling the phases of ordinary matter emerging at quantum criticality and behaving like dark matter, implies scaling up of Compton lengths and other quantum lengths making possible quantum coherence at longer scales than usually. The hierarchy of Planck constants has now a rather strong theoretical basis and reduces to number theory [24, 25]. Quantum criticality is essential and could help to explain the difficulties to replicate the effect.

2. Pollack effect serves as the mechanism of cold fusion. Irradiation of water in the presence of gel phase generates negatively charged exclusion zones (EZs) inside which water has the stoichiometry $H_{1.5}O$. These zones exclude various inpurities, which suggests a kind of time reversed diffusion. 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 keV range. These in turn transform to ordinary nuclei.

3. Gravitational flux tubes of Earth or Sun, with gravitational Compton length L_{gr} equal to one half of Scwartscild radius $r_s = GM/\beta_0$, where $\beta_0 \leq 1$ is velocity parameter, is one option. For the Earth one has $\beta_0 \simeq 1$ and $L_{gr} \simeq .5$ cm. For the Sun one has $\beta_0 \simeq 2^{-11}$ and $L_{gr} \simeq R_E/$, , where R_E is the radius of Earth.

4. There are also options characterized by much smaller effective Planck constant h_{eff}. In particular, negatively charged systems involve magnetic bodies characterized by electric Planck constant h_{em} [28] proportional to the total charge of the system (DNA, cell, and Earth are basic examples). Also the EZs created in the Pollack effect have large electric charge. Pollack effect would create dark protons and also induce the generation of dark electrons. Whether the dark electrons reside at separate monopole flux tubes or whether the effective Planck constants are identical is not clear.

2.2.2 The role of Pollack effect

Pollack effect provides the mechanism of "cold fusion" identified as dark fusion.

1. Pollack effect near the catalyst surfaces would create exclusion zones (EZs) as negatively charged regions. In the transformation of dark nuclei to ordinary nuclei, practically all ordinary nuclear binding energy is liberated. This could create the reported craters at the surface of the target and also contribute to heating. Dark nuclei could also leave the system. Note that dark protons would quite generally play a key role in catalysis which conforms with the fact that "cold fusion" takes place near catalyst surfaces such as metal hydrides.

2. 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. Dark strong interactions would be rather fast and the dark nuclei at the magnetic flux tubes could be rather stable in the final states. If the dark stability means the same as the ordinary stability, also the isotope shifted ordinary nuclei would be stable. The spectrum of the ordinary nuclei would reflect that of dark nuclei.

3. How to understand the poor replicability of cold fusion? Quantum criticality would make dark fusion difficult to realize since fine tuning of the control parameters is required. The dark nuclei or their decay products at the flux tubes leading from the system to the external world could be lost as also a considerable part of the liberated energy. The long lifetime of dark nuclei against transformation to ordinary nuclei would mean that only X rays as dark counterparts of gamma rays would contribute to the heating and gamma rays would not be detected.

4. Note that dark nucleosynthesis could serve as the mechanism of ordinary nucleosynthesis outside stellar interiors and explain how elements heavier than iron are produced. Nuclei would be created from dark nuclei. This mechanism could allow at least the generation of nuclei heavier than Fe, not possible inside stars. Supernova explosions would not be needed to achieve this. Also the formation of protostars could begin with dark fusion, which gradually heats the system so that the ordinary fusion is eventually ignited. One can also ask whether even the hot fusion assumed to occur inside stars could be actually cold fusion.

2.2.3 Dark fusion

The most interesting things would occur at the level of dark nuclear physics, which is now a key part of TGD inspired quantum biology.

1. EZs would be created as protons are transfered to the magnetic monopole flux tubes. At the flux tubes protons would have $h_{eff} = nh$ and form dark variants of nuclear strings. Also ordinary nuclei are predicted to be string like entities [17].

2. Dark nuclear binding energy would be measured using as a natural unit ordinary nuclear binding energy scale MeV/n, rather than MeV. The most plausible interpretation is that the field body/magnetic body of the nucleus has $h_{eff} = nh$ and is scaled up in size. $n \simeq 2^{11} \simeq m_p/m_e$ is favoured by the fact that from Holmlid's experiments the distance between dark protons should be about electron Compton length. This would suggest that the electric field of EZ determines the value of effective Planck constant and one has $h_{eff} = h_{em}$. This predicts 1-10 keV energy scale for the dark counterparts of gamma rays emitted in dark beta decays.

3. The simplest possibility is that the protons are just added to the growing 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 [1, 3].

Concerning the identification of the monopole flux tubes, the candidates are the gravitational monopole flux tubes of the Earth or the Sun and electric flux tubes assignable to the EZs.

1. The assumption is that monopole flux tubes carry "endogenous" magnetic field with a normal value $.2B_E = .2$ Gauss and that the velocity parameter $\beta_0 = v_0/c$ appearing in the expression $\hbar_{gr} = GMm/\beta_0$ is $\beta_0 \simeq 1$ for the Earth and $\beta_0 \simeq 2^{-11}$ for the Sun.

   For the Earth, the dark cyclotron energy, which does not depend on the mass m of the charged particles, is about 5 eV which exceeds the gravitational binding energy of of proton about 1 eV so that its liberation can kick proton from the gravitational field of the Earth. For the Sun, the dark cyclotron energy is 10 keV. Could the monopole flux tubes assigned with dark protons in dark fusion be identified as monopole flux tubes of the Sun?

2. The value $h_{eff}/h \simeq 2^11$, much smaller than the gravitational Planck constant of the Earth, would suggest that the electric field of EZ determines the value of effective Planck constant and one has $h_{eff} = h_{em}$.

2.2.4 The origin of negative ions in Tohoku experiments

The presence of Ni^-, Cu^-, C^-, Si^-, O^- and H^- ions in the target serves as an important guideline. Also W-L model involves negatively charged surfaces at which the presence of electrons is thought to catalyze transmutations. In TGD, Pollack effect generating EZs, would serve as the ionization mechanism.

1. The appearance of negative ions in the entire target volume in the final state could be understood in terms of melting.

2. What is remarkable is the appearance of O^- iond. The Coulomb wall makes it very implausible that the adsorption 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, also present in air, is not detected in the target so that the leakage of oxygen to the target looks implausible. Could the leakage of oxygen rely on a less direct mechanism?

3. Oxygen and hydrogen appear as molecules. O_2 resp. H_2 has a binding energy of 5.912 eV resp. 4.51 eV. Therefore the reaction $2H_2 + O_2 \rightarrow 2H_2O$ could occur during the pressurization phase. The energy liberated in this reaction is estimated to be about 4.88 eV (see this).

4. Water plays a key role in the Pollack effect interpreted as a formation of dark proton sequences. Pollack effect and its generalization to metal hydrides generates EZs as negatively charged regions

and Ni^-, Cu^-, C^-, Si^-, O^- and H$^-$ ions would serve as a signature of these regions. In the "cold fusion" based on electrolysis, the water would be present from the beginning but now it would be generated by the proposed mechanism.

2.2.5 The role of the catalyst in the process

In electrolysis experiments and in quantum biology, the presence of gel phase bounding the water acting as a catalyst makes possible Pollack effect near the boundary, where EZs are formed.

1. The initial and final states of the reaction have almost the same energies: the final state energy is above IR energy of about .1 eV corresponding to physiological temperature 100 K. Overcoming the energy wall requires energy of order of bonding energy of water molecules about 5 eV. The gel phase naturally acts as a bio-catalyst providing temporarily energy making it easier to overcome the energy wall preventing the transformation the splitting of water molecue to water ion and dark proton.

2. In the simplest situation, the reaction $H_2O \rightarrow HO^- + p$, p dark proton, takes place. The local hexagonal lattice structure of water is preserved in the phase transition producing "fourth phase of water". A phase transition of water is involved. The arrow of time could change at the magnetic body associated with the EZ. This explains the exclusion property in terms of time reversed diffusion. The reaction $2H_2+O_2 \rightarrow 2H_2O$ could produce an excitation with energy, which is almost the height of the potential wall, preventing the splitting of $OH \rightarrow O^- + p$.

3. In Tohoku experiments metal hydrides acting as catalysts are used. The catalysis would most naturally occur at the negatively charged metal hydride boundaries of the layers and lead to the formation of EZs. Pollack effect generalizes to metal hydrides so that OH bond can be replaced with metal-H bond splitting to metal ion and dark proton and would occur spontaneously for metal hydrides.

   The transformation of ionized metal hydride ions to neutral form by the reverse Pollack effect could liberate energy as a photon inducing the Pollack effect for the excitations of water molecules. The catalyst property could be almost synonymous with the possibility of spontaneous Pollack effect.

2.2.6 Pollack effect from the point of view of zero energy ontology

The reaction $2H_0+O_2 \rightarrow H_2O$ proposed to occur in Tohoku experiment is the reversal of water electrolysis (see this). It however seems that these two reactions are not genuine time reversals of each other. Since a tunnelling through the potential barrier must occur in both cases, it seems that two "big" state function reductions (BSFRs) changing the arrow of time [19] could occur in both cases. This does not depend on whether the reaction is exothermic or endothermic.

Also the Pollack effect would involve two BSFRs. One can imagine several ZEO based models for the Pollack effect based on the TGD view of quantum tunnelling as two BSFRs, each changing the arrow of time. The following is one possible guess.

1. Assume that the presence of the catalyst makes the system *catalyst + water molecule* quantum critical. The system would be in a superposition of states $C(E) + H_2O(E_w)$ and $C(E - \Delta E) + H_2O(E_w + \Delta E)$ and the water molecule and catalyst are entangled. One can speak of energy entanglement.

   The energy of H_2O in the latter state is near the top of the potential barrier preventing the splitting of $H_2O \rightarrow HO^- + p$, where the dark proton p is at the gravitational magnetic flux tube. The absorption of the Pollack photon γ makes this decay possible and it reduces essentially to a transition $OH \rightarrow O^- + p$ [29].

2. In the ZEO based view of quantum tunnelling, the transition would be induced by two SFRs. In the initial state, the catalyst C would be entangled with the water molecule and one would be a superposition $C(E) + H_2O(E_w)$ and $C(E - \Delta E) + H_2O(E)$, $E = E_w + \Delta E$. One can speak of energy entanglement. This state is quantum critical.

3. In the first BSFR, induced by the absorption of Pollack photon with energy $E(\gamma)$, the state becomes a superposition of the states $C(E - \Delta E) + H_2O(E_1)$ and $C(E - \Delta E) + (HO^- + p)(E_1)$, $E_1 = E_w + \Delta E + E(\gamma)$. It evolves in the reversed direction of geometric time.

4. In the second BSFR, the state $C(E - \Delta E) + (HO^- + p)(E_1)$ can be selected and evolves in the standard time direction and decays spontaneously by emitting a virtual photon with energy ΔE absorbed by C so that a 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 about 1 eV. .3 eV is the energy scale for the difference of the bonding energy of OH bond and binding energy of e^- in OH^- ion [29].

2.3 Summmary

The earlier TGD based model applying to the electrolysis based "cold fusion" is generalized. The reversal $2H_2 + O_2 \rightarrow 2H_2O$ of water electrolysis transforms the situation to that appearing in ordinary "cold fusion". If water molecules are created in an excited state near the top of the potential barrier preventing Pollack effect, no catalyst is needed. Pollack effect could occur spontaneously for metal hydrides and its reversal could generate photons inducing the Pollack effect for water, producing oxygen ions not present in the initial state. Biocatalysis would quite generally rely on the generalized Pollack effect.

The dark protons combine to form dark nuclear strings. Weak decays would produce nuclear strings containing also neutrons. Their spontaneous transformation to ordinary nuclei would give rise to nuclear transmutations and liberatie almost all ordinary nuclear binding energy. If the rate of this process is slow, it does not contribute considerably to the heating. Nuclear gamma rays are replaced with X rays for dark nuclei so that the basic objection against "cold fusion" is overcome. The quantum criticality at the phase transition inducing Pollack effect explains why "cold fusion" experiments are difficult to replicate.

The heat production rate is higher during the desorption phase than during the adsorption phase. The reason would be that the dark proton sequences have reached a full length during desorption and can produce more dark nuclei as they decay. Also the amount of the produced water is maximal. The TGD based model predicts much more than is reported in the article of Iwamura et al. A spectrum of light nuclei would be produced in the process and contain at least alpha particles but there is no information about the spectrum in the article.

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