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Research Article

Transmutations Involving the Di-neutron in Condensed Matter

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Abstract

It has been recently revealed how a lattice bound proton, in an electrochemical cathode, can absorb a relativistic electron yielding a neutron. There is no longer much doubt that the analogous electron capture by a deuteron, in condensed matter, $(e^-_{\mathrm{real}} +^1 p_{\uparrow 0}n_{\uparrow} \rightarrow {}_0n_{\downarrow 0}n_{\uparrow} + \nu_e)$ is even more efficient, where the arrows indicate nucleon spins. The life time of the newly formed di-neutron may be vanishingly short, but in the palladium deuteride matrix, we show that it is certainly sufficiently long to undergo transmutation with constituents of the matrix as well as added "impurities" to yield both isotopic and isotonic products: i.e. $({}_0n_{\downarrow 0}n_{\uparrow} +^{106}\mathrm{Pd} \rightarrow {}^{108}\mathrm{Pd})$. When the agent capturing the di-neutron is ^{1}H, tritium is the result. When it is ^{2}H, ^{4}He and heat are the products (the Fleishmann Pons Heat Effect). Consistent with the tendency of di-neutrons to cluster, multiple di-neutrons are occasionally captured yielding neutron heavy nuclei. This is followed by beta decay and the respective isotonic products. We show that, within the PdD matrix, these di-neutron reactions involve phonon enforced quantum tunneling. The di-neutron-phonon mechanism fully accounts for the following: (1) the evolved heat commensurate with ^{4}He production, (2) the production of tritium when small amounts of ^{1}H are present, (3) the release of feeble neutrons, (4) the formation of Pr when Cs is present, (5) the ostensive intermittent reproducibility and erratic (chaotic) heat out-puts, and (6) the seemingly major problem of obfuscating the Coulombic repulsion issue. Indeed, the antics of the di-neutron can fully explain the important aspects of normal temperature LENR heat effects and transmutations. Further, the di-neutron paradigm (mechanism) falls within the normal bounds of the Standard Model, and it is without the necessity of exotic forms of matter.

Keywords: Chaos, Di-neutron, Electron Capture, ^{3}H, ^{4m}H, Palladium-128, Transmutation

1. Introduction

Although not the most probable path to the lightest heavy isotope, it took only about three minutes after the Big Bang for proton–neutron collisions to begin forming deuterons $(\mathrm{H}^+ + {}_0n \rightarrow {}^2\mathrm{H}^+ + \gamma)$. The first atoms, to be formed in our universe, resulted from the capture of electrons by protons in free space (FS) to yield atomic hydrogen. That action

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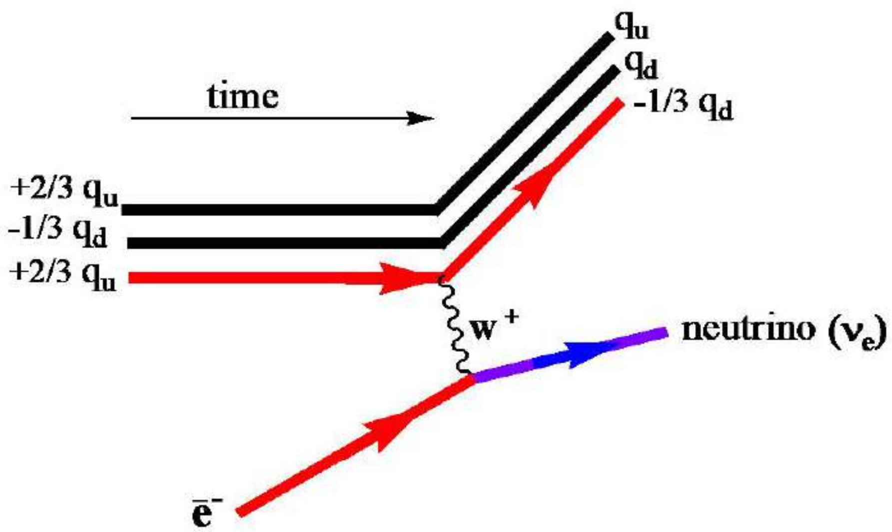

Figure 1. The Feynman diagram for the capture of a relativistic electron by an up quark which, in turn, becomes a down quark. In this process, a very short lived W^+ boson is emitted by the up quark that annihilates the electron to yield an electron neutrino.

originated about 380,000 years later. This seemingly simple process (reaction 1) is actually more fascinating than first meets the eye. If the electron comes in "heavy" (with relativistic energy: $E = (pc)^2 + (m_0c^2)^2$), it can bore in closer to the nucleus than the Bohr radius of 529 pm. In this range, the wave function for the relativistic electron ($\bar{e}^-$) can overlap with weak force fields carried by the W and Z^0 bosons. The W boson interaction results in the merging of the electron (e^-) with the proton and consequent formation of a neutron ($_0n$) and a neutrino. Since the weak force is involved, reaction 2 is best illustrated by a Feynman diagram, Fig. 1.

$$^1H^+ + e^- \rightarrow H^\cdot, \tag{1}$$

$$^1H^+ + \bar{e}^- \rightarrow {}_0n + \nu_e. \tag{2}$$

Interestingly, if the incoming electron interacts with the Z^0 weak force boson, it is repelled by the proton ($^1p = {}^1H^+$) and is scattered off via the weak hypercharge [1]. Since the weak force does recognize parity, the scattering is different depending upon how the electrons are polarized (Fig. 2) [1]. The weak force is the fundamental force that recognizes parity.

The mutual capture of the protons and neutrons (reaction 3) gives rise to isotopes, and as indicated the deuteron is a spin triplet. At first, this seems contradictory to the Fermi–Dirac rules of degeneracy pressure: no two fermions, comprising a single entity, can be in the same quantum state. The strong nuclear force, which binds the two baryons in

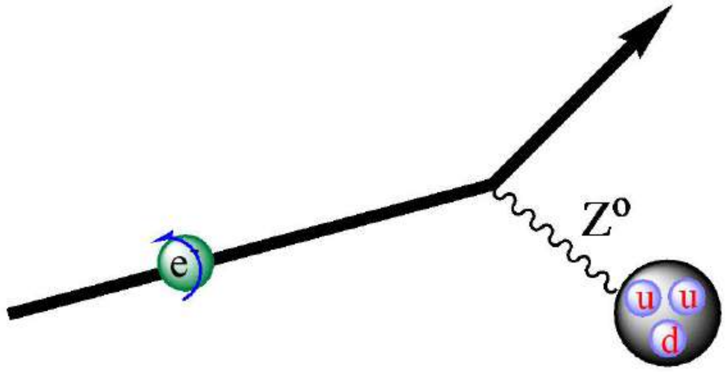

Figure 2. A cartoonish diagram of the scattering of a left-handed electron by a proton (two up quarks and one down quark). The scattering is due to weak neutral currents (the Z^0 boson). Parity violation in this weak interaction yields a scattering asymmetry (different scattering for left and right-handed electrons). The measurement is carried out by firing polarized beams of electrons through an unpolarized liquid H_2 target. The proton's weak charge has a value of 0.0719 ± 0.0045 [1].

reaction 3, cannot feel charge differences or the very small mass difference between ${}_0n$ and ${}^1p$. Consequently, another quantum Eigen value is required to explain the deuteron. Isospin was originally invented by Werner Heisenberg to distinguish between the proton and neutron, and explain the stability of the deuteron (${}^1p_0n$), which is an isospin singlet. The detailed mathematical model for isospin was worked out five years later, in 1937, by Wigner [2].

$$ {}^1H^+ + {}_0n \rightarrow {}^1p_{\uparrow 0}n_{\uparrow}. \quad (3)$$

The two fermions occupying the helium-2 nucleus (the di-proton (${}^1p^1p$)) must be also anti-symmetric under exchange and obey Fermi–Dirac statistics. It would clearly be an isospin triplet and also suffers from Coulombic repulsion pressure. For these reasons, the nucleus of ${}^2He$ has never been detected. The remaining di-nucleon is the di-neutron (${}_0n_0n$) [3], and it has major chemical significance in the condensed phase. Writing in *Chem. Rev.* [4], Pekka Pyykkö claimed that a bound di-neutron (${}_0n_0n$) would be "the ultimate noble-gas molecule." He also correctly predicted the effects of relativistic electrons in gold, cesium, and other heavy elements [5,6]. Unlike ${}^1p^1p$, ${}_0n_0n$ would exist in the absence of Coulombic repulsion.

Forty years prior to Pyykkö's review article [4], calculations carried out by Migdal [7,8] suggested that the di-neutron is, however, unbound, but these early calculations did not the halt the empirical search for the bound di-neutron [9]. Interest in finding the ${}_0n_0n$ was further discouraged just five years later when effective range considerations again suggested an unbound state [10]. Hence, isospin and other theoretical considerations seem to favor an unbound free space di-neutron (FS_{nn}). On the other hand, Migdal suggested that the di-neutron could exist in the vicinity of a neutron heavy nucleus. Consistent with Migdal's predictions [11,12], di-neutrons were shown to exist as semi-isolated entities in neutron heavy exotic nuclei like ${}^5H$, ${}^6H$, and ${}^8He$ [13]. Disbelief in the bound ${}_0n_0n$ grew even as confirming empirical observations were periodically reported. For example, in 1993, Bertulani et al. found that the energy needed to remove a pair of neutrons from ^{11}Li is 200 keV, while that needed to remove a single neutron is 1 MeV [14]! A possible empirical suggestion of $_0$n$_0$n first appeared in the same year that the Pyykkö paper (2012) appeared. At the National Super conducting Cyclotron laboratory, ^{16}Be was generated via beam–target collisions. The ^{16}Be was found to immediately decay by di-neutron emission to ^{14}Be, and the two neutrons "fly off" as a pair [15,16]. If isospin were to have caused the sputtering apart of the two neutrons, they should have flown away in opposite directions. The authors of the ^{16}Be decay paper state: "The di-neutron character of the decay is evidenced by a small emission angle between the two neutrons." However, it should be mentioned that this paper has been discussed in the literature over 60 times, and the vast majority of these articles conclude, via theoretical arguments only, that the two neutrons observed in ref. 15 were not bound. On the other end of the argument, it has been suggested that the existence of a bound FS$_{\mathrm{nn}}$ is consistent with Big Bang nucleosynthesis [17]. In 2014, Hammer [3] used Lagrangian calculations to resurrect some theoretical possibility of a ^{1}S$_0$ free space di-neutron (FS$_{\mathrm{nn}}$) [3]; in this paper [3] he states that $_0$n$_{\downarrow 0}$n$_\uparrow$ " cannot be excluded to next-to-leading order in pionless EFT." Hammer's statement seems in contrast to the vast majority of quantum mechanical conclusions concerning the FS$_{\mathrm{nn}}$, but his work is too important to ignore.

Witała and Glöckle incorrectly stated that even a slightly bound di-neutron might solve some open problems involving break-up reactions (e.g. reaction 4). Their computations turned out to be incorrect and their reaction will probably remain only a hypothetical "Gedanken-reaction" in free space [18–20]. However, we will provide evidence that an analogous "ship in a bottle" type synthesis (reaction 5) really results in a ^{1}S$_0$ condensed phase di-neutron with a life time sufficiently long to allow its involvement in transmutation and "Fleishman Pons Heat Effect" reactions.

$$ {}_0\mathrm{n} + {}^1\mathrm{p}_{\uparrow 0}\mathrm{n}_\uparrow \rightarrow {}_0\mathrm{n}_{\downarrow 0}\mathrm{n}_\uparrow + {}^1\mathrm{p}, \tag{4} $$

$$ \bar{\mathrm{e}}^- + {}^1\mathrm{p}_{\uparrow 0}\mathrm{n}_\uparrow \rightarrow {}_0\mathrm{n}_{\downarrow 0}\mathrm{n}_\uparrow + \nu_{\mathrm{e}}. \tag{5} $$

History, astonishingly, reveals a multitude of speculations and calculations on even more complicated assemblies of neutrons: clusters of di-neutrons [21]. A number of empirical observations [21,22] of the breakup of ^{14}Be suggest that a multi-neutron cluster is liberated. Most probably it arises from the reaction: $^{14}\mathrm{Be} \rightarrow {}^{10}\mathrm{Be} + ({}_0\mathrm{n}_0\mathrm{n})_2$ [21]. According to Bertulani (the winner of a number of awards in nuclear physics including the John Simon Guggenheim Memorial Foundation Fellowship), the tetra-neutron can exist as a kind of "di-neutron–di-neutron molecule," in which the Hamiltonian would be:

$$ H = -(\hbar^2/2m_{0\mathrm{n}}) \sum_{i=1}^{i=4} \Delta_i + V, $$

where *V* is the neutron–neutron potential [21]. Confinement in condensed matter would hinder escape and render $_0$n$_0$n–$_0$n$_0$n, as a resonant state, much more tenable than it would be in free space. The di-neutron cluster is not essential to LENR, but the formation of at least a transient associated pair of neutrons, in condensed matter, is.

2. Results and Discussion

The electron has a gyromagnetic ratio that is more than two orders of magnitude greater than that of the proton. Hence, deuteron electron capture (reaction 5) results in symmetry breaking and consequent flipping (scrambling) of the resulting neutron spin. When the two spins land in the singlet state, the di-neutron is trapped intact ("ship in a bottle"), and is trapped in the absence of degeneracy pressure as a ^{1}S$_0$ condensed matter entity (Fig. 3).

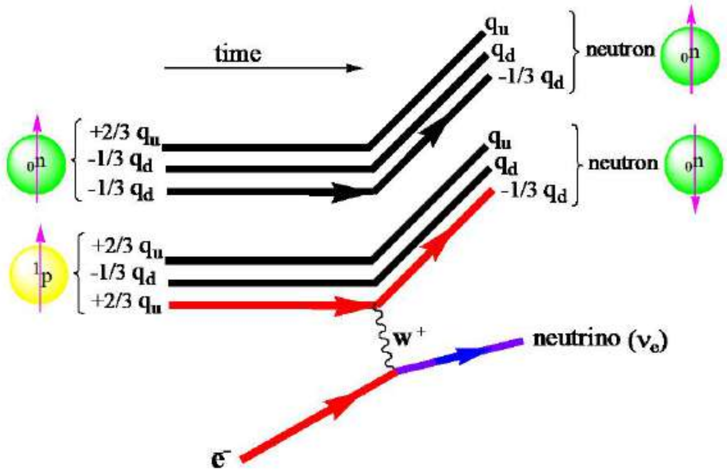

Figure 3. A Feynman diagram for the capture of a relativistic electron by a proton (two up quarks and one down quark) and decaying to a neutron (two down quarks and one up quark) and an electron neutrino. The breaking of spin (purple arrow) symmetry by the proton spin flip allows the newly formed neutron to become one member of a ($n_{\downarrow}n_{\uparrow}$) of singlet spin in condensed matter.

Although a free space reaction 4 is not reasonable [18,19], a viable reaction that is stoichiometrically similar, reaction 5 appears to take place in condensed matter. Widom and Larson have provided a mechanism that is free of Coulombic repulsion, for an electro-chemical electron capture processes ($e^- + {}_z\mathrm{A} \rightarrow {}_{z-1}\mathrm{A} + \nu_e$) in condensed matter [23]. This yields low momentum neutrons when ${}_z\mathrm{A} = {}^1\mathrm{H}$. Due to the large mass energy ($E = m_0c^2$) of the muon (μ^-), the analogous reaction involving the muon (μ^- in reaction 6) occurs spontaneously after simply mixing muons into a hydrogen system [24]. Reaction 6 continuously takes place in Earth's upper atmosphere. However in contrast, shooting muons through a thin film into deuterium produces a pair of non-interacting neutrons, reaction 7 [25], and these empirical results are consistent with a calculated (LO perturbation theory) negative scattering length (a_{nn}) of $-22.9\pm$ 4.1 fm [26]. This is evidence for the non-existence of a bound $\mathrm{FS}_{\mathrm{nn}}$. Also, Using a neutron beam, ${}_0$n capture breakup experiments produced results calculation-ably compatible with an a_{nn} value of $-18.7\pm$ 0.7 fm for the ${}^1\mathrm{S}_0$ $\mathrm{FS}_{\mathrm{nn}}$ described in reaction 4 [27].

$$\mu^- + {}^1\mathrm{p} \rightarrow {}_0\mathrm{n} + \nu_\mu, \tag{6}$$

$$\mu^- + {}^1\mathrm{p}_{\uparrow 0}\mathrm{n}_{\uparrow} \rightarrow {}_0\mathrm{n} + {}_0\mathrm{n} + \nu_\mu. \tag{7}$$

The muon is much heavier than is the electron, however, in condensed matter, the electron energy can be augmented by local electromagnetic field fluctuations due to vibrating electric and magnetic multi-pole moments [23,28,29]. Such fluctuations ("condensed matter Zitterbewegung") [29] add velocities to the electrons (e.g. emitted from the anode) in directions other then x translation. They also can lead to greatly enhanced quantum tunneling via phonon interaction [30]. Writing in Science, Ben Powell (in a perspective of Hassan et al. [31]) explains how low energy excitations in condensed-matter can be very different than the electrons, neutrons, and protons that make up the material because the periodic array of atoms breaks translational and rotational symmetries. Consequently, "heavy" relativistic electrons, when injected in an appropriate lattice, can be absorbed by lattice deuterons resulting in viable low momentum di-neutrons, as described in Fig. 3. To find the consequences of such di-neutrons, we should look for anomalous isotopic augmentations ($e^- + {}^2H^+ + {}^mA \rightarrow {}^{m+2}A$) observed after electron injection into lattice material containing deuterons. Actually, such experiments have been carried out [32].

In a much over looked article published in *Analytical Chemistry* in 1991, D. Rolison and W. O'Grady revealed empirical confirmation of nuclear transmutation resulting from palladium foil electrolysis in D_2O [32]. They utilized time of flight mass spectroscopy (TOF-SIMS) to analyze samples before and after electrolysis. Their results were thought to be a result of isotopic anomalies. The puzzling aspects of their data arise from the ostensibly "simple" addition of a di-neutron to ^{106}Pd to yield ^{108}Pd. The natural abundance of palladium-106 is 27.33% while that of palladium-108 is 26.46%. However, during the electro-reduction of D_2O using a palladium deuteride cathode, the ratio of these two isotopes began to merge; and after 10 min of electrolysis, the abundance on the cathode surface of ^{108}Pd (atomic wt. 107.9038917) was found to be greater than that of ^{106}Pd (atomic wt. 105.9034857). The corresponding transmutation (reaction 8), assisted by phonon enforced quantum tunneling effects, represents a gain of 2.000406 mass units. This is extremely strong evidence for, at least, a short lived associated pair of neutrons in the condensed phase.

$$e^- + {}^1p_{\uparrow 0}n_{\uparrow} \rightarrow {}_0n_{\downarrow 0}n_{\uparrow} + {}^{106}\,\mathrm{Pd} \rightarrow {}^{108}\mathrm{Pd}. \tag{8}$$

Early on, the Rolison–O'Grady results did not garner the deserved recognition for two basic reasons: (1) The di-neutron was then thought to not exist and (2) Isotopic augmentation was perceived as very controversial, because nuclear effects observed in ambient temperature chemical systems were unknown. In fact, a Widom Larson type electron capture followed by a condensed matter fusion is the only reasonable mechanism for their observed ^{106}Pd to ^{108}Pd transmutation. In contrast to the early lack of recognition and as testimony to the scientific rigor and accuracy of their empirical observations [32], Debra R. Rolison won the prestigious William H. Nichols Medal for original research in 2018.

More recent experiments carried out by Jean-Paul Biberian revealed similar transmutations with the isotopes of silver [33]. Following electrolysis of a thin film of silver impregnated palladium deuteride on silicon, a mass spectral SIMS surface analysis revealed an isotopic ratio of ^{109}Ag/^{107}Ag to be 10, while the natural abundance ratio is 1.06 (see reaction 9). Since both the Pd and Ag isotope studies were carried out with the inclusion of all proper control experiments, including analysis before and after electrolysis, error seems unlikely. It is always possible that contamination spoiled only the post-electrolysis sample, but this is extremely unlikely in both studies. Further, contamination with an unnatural isotope distribution seems absurd, especially since we are dealing with highly regarded and even award winning scientists.

$$^{107}\mathrm{Ag} + {}_0n_0n \rightarrow {}^{109}\mathrm{Ag}. \tag{9}$$

Reactions 8 and 9 demonstrate that the di-neutron serves as a transmutation reactant. Since di-neutrons have a tendency to cluster [21,22], analogous reactions (transmutations) involving the tetra-neutron might be anticipated. The fusion of $({}_0n_0n)_2$ (or just two di-neutrons) with a stable nucleus would most likely result in an unstable nuclear product with too many neutrons relative to protons. The result of this would be beta (β^-) decay and a stepping up in atomic number. An irrefutable display of this phenomenon was reported by Iwamura and his team at the Mitsubishi Labs [34]. Iwamura et al. took advantage of the ability of cesium metal to inject electrons into a reducible lattice. Specifically, they synthesized a multi layer sandwich complex with bulk Pd on the bottom, alternating CaO and Pd layers in the middle, and a Pd thin film on top. They then deposited Cs metal (from the vapor) onto the top layer [34].

Cs is an ideal selection, as ^{133}Cs has a natural abundance of 100%, and Cs has the lowest ionization potential of the stable elements. Deuterium gas was then passed through the sandwich complex. Given the experimental procedures that lead to reactions 8 and 9, this arrangement should produce a relatively large burst of di-neutrons due to the flow of D_2 directly through the electron encrusted palladium manifold. Post-reaction analysis of the top layer yielded the unmistakable presence of praseodymium-141! ^{141}Pr was, of course, not present on the pre-reaction sandwich. Anyway, Pr would be a most improbable contaminant. Apparently, ^{133}Cs fused with four di-neutrons, or possibly two of Bertaluni's tetra-neutrons, to yield ^{141}Cs. This isotope is unstable and undergoes β^- decay ($t_{1/2} = 25$ s), ultimately yielding ^{141}Pr (reactions 10–12). The presence of ^{141}Pr is apparently a result of the tendency of di-neutrons to cluster. Other transmutation products via ostensible fusion with di-neutron clusters were observed by the Mitsubishi group: for example the formation of samarium from barium [34]. It is suspected that an analogous birth is possible for a number of rare earth elements.

$$2\,{}^{133}\mathrm{Cs} + 2\,{}^{1}\mathrm{p}_0\mathrm{n} \rightarrow ({}_0\mathrm{n}_0\mathrm{n})_2 + 2\,{}^{133}\mathrm{Cs}^+, \tag{10}$$

$$2\,({}_0\mathrm{n}_0\mathrm{n})_2 + {}^{133}\mathrm{Cs}^+ \rightarrow {}^{141}\mathrm{Cs}, \tag{11}$$

$${}^{141}\mathrm{Cs} \rightarrow {}^{141}\mathrm{Pr} + 2\beta^-. \tag{12}$$

3. Conclusions

For the case of the W boson mediated $e^- - {}^1p$ interaction, a high energy neutron is usually the result (Fig. 1). However, when the proton is a member of a deuteron, a di-neutron is formed, which in the condensed phase can have very low momentum and participate in low energy transmutations. It has been shown here that the di-neutron, which exists as an isospin triplet and a spin singlet (Fig. 3), can be found in deuteriated cathodes during electrolysis. Di-neutron activity is suspected from the otherwise unexpected presence of unnatural heavy isotopic materials as revealed in [15,17] (see reactions 8 and 9). When such systems are very neutron heavy, β^- decay can lead to rare isotonic products as reported by Iwamura et al. (see reactions 10–12) [34]. It may be too early to consider possible synthetic proposals involving these transmutation reactions, but the search for otherwise unexpected isotopes and isotones having resulted from di-neutron fusion should be considered.

Simple electrochemical experiments, as described in reactions 8–10, followed up with radiological analysis should demonstrate the occurrence and perhaps usefulness of proposed syntheses. For example, $^{238}UD_3$ is a well studied and useful compound [35] and treatment of ^{238}U with ${}_0n_0n$ via the electrolysis of $^{238}UD_3$ impregnated PdD would lead to uranium-240 ($^{238}\mathrm{U} + {}_0\mathrm{n}_0\mathrm{n} \rightarrow {}^{240}\mathrm{U}$). Uranium-240 has a half life of 14.1 h and decays via β^- emission to ^{240}Np. ^{240}Np, in turn, undergoes further β^- emission ($t_{1/2} = 61.9$ days) to produce ^{240}Pu. The radiological signature of this process would be relatively easy to identify and not require work up and high resolution mass spectral analysis to prove out the viability of the process. A plethora of analogous schemes involving actinides and lanthanides, which are in high demand, are not difficult to imagine.

Finally, it should be mentioned that, in palladium hydride, deuterons or deuterium can readily absorb relativistic electrons to form di-neutrons, but the deuterium must first be freed from bonding to the Pd. This situation is readily met, as there is a plethora of electrons from metals with low ionization potentials (i.e. Cs) or from an external anode. Solid state crystals of polyaromatic hydrocarbons, and their electron rich anion radicals serve as explicit examples of this added electron enforced bond destabilization [36]; the electron preferentially destabilizes the isotopically heavy bond. As a result, warming of anion radical crystalline salts, where the added electrons are now in a conduction band of the solid material, results in bond rupture and hydrogen evolution [37,38]; added electrons attenuate the barrier to bond rupture [39]. The added electrons, whether from an anode or Cs metal, protrude into anti-bonding bands, and relative Pd–D (H) bonding decreases due to zero point energy differences (D relative to H) [36–39].

Nobel Laureate Roald Hoffmann wrote [40]: "In general, the interactions on a solid surface resemble those in molecules," and: "shifts of electron density around the Fermi level, have bonding consequences." This means that the electron count has an important bonding influence on the solid lattice surface that is analogous to what has been observed for molecules in solution [41]. The addition of a sufficient number of electrons to the PdH or PdD system requires that the added electrons go into anti-bonding orbitals (solution) or bands. Electron addition destabilizes the individual bonds, more so for the isotopically heavy (deuterium) systems. This bond rupture, followed by electron capture, di-neutron formation, and transmutation is illustrated in Fig. 4.

It is actually very unlikely that a given electron will be able to approach the nucleon sufficiently close in order to quantum mechanically overlap with the weak field of the nucleon, but it does happen. And, when it does, reaction 5

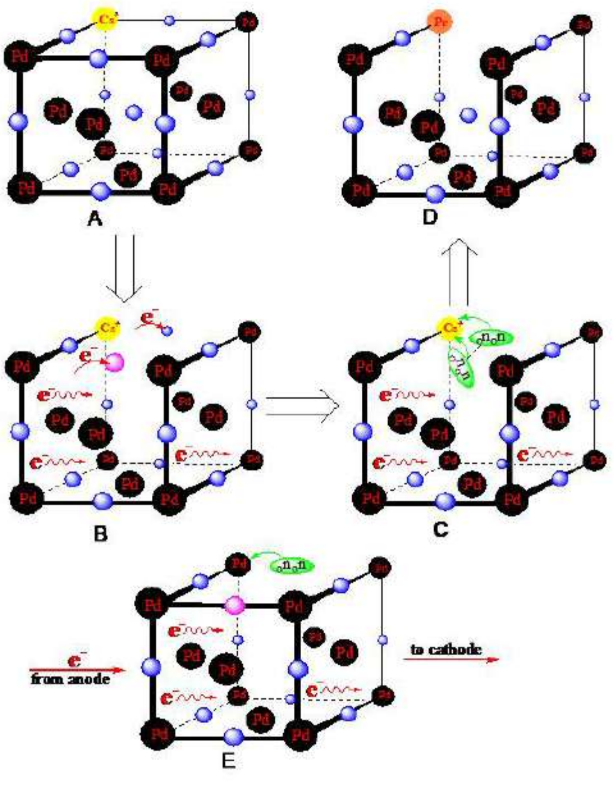

Figure 4. (A) Representation of a single surface cell of Cs impregnated PdD lattice with one face centered Pd atom missing. (B) Electron infusion from the Cs changes the electron count, and Pd–D bond breakage takes place followed by deuteron capture of the Zitterbewegung-ing electrons. (C) Newly formed low momentum di-neutrons may be attached, and the tetra-neutron fuses with a nearby cesium. (D) The heavy cesium becomes Pr (via ^{141}Cs beta decay (reaction 10). (E) In the case of the Rolison O'Grady experiment [32], the electrons come from an attached anode and the di-neutrons fuse with a ^{106}Pd to form its heavier isotope: ^{108}Pd.

takes place followed by considerable local heating. The local heating makes it more probable for a similar nearby event, which produces even more heat; hence, a cascade of events proceeds. This also explains the observation of transmutation products clumped together in "hot spots" on the post-electrolysis cathode surface [42]; phonon enforced quantum tunneling is clearly involved [30].

Quantum tunneling is sufficiently important to be dubbed the "The Third Reactivity Paradigm" of chemical reactions [42]. We have observed how the involvement in tunneling can change the quantum nature of subatomic particles [43,44]. For example the EPR spectrum of a tunneling electron renders all proton hyperfine interactions invisible and shifts the resonance field by nearly a gauss [44]. The observables of di-neutrons in condensed matter are likewise perturbed, as they are always close enough to transmutation active species and surrounded by phonon activity to be involved in active quantum tunneling. As mentioned above, it has been shown how surface phonon waves can drive disparate quantum systems [30]. Hence, both the deuteron electron capture (Fig. 3) and the di-neutron addition (Fig. 4) are surface reactions that involve phonon assisted quantum tunneling to yield the transmutation products, "hot spots," etc. [45]. Phonons are one of the two cornerstones of condensed matter (the other being the electron) [46].

This same phonon tunneling ${}_0n_0n$ transmutation activity, also leads to the formation of heat, tritium, and ^{4}He during observation of the FP heat effect [47,48]. Electrolysis of a PdD/H system causes the preferential release of

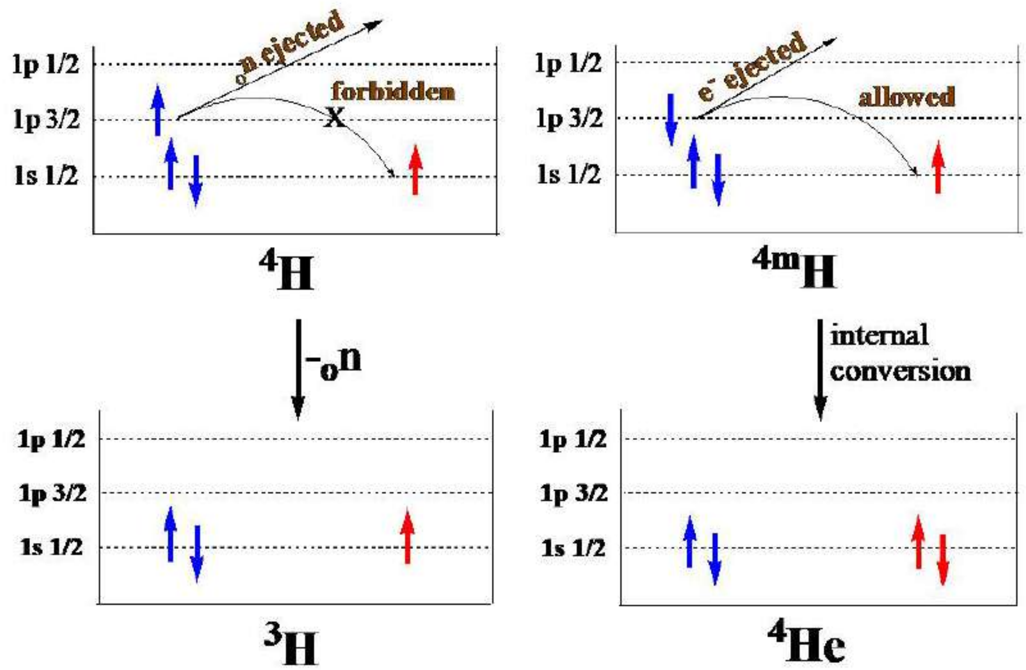

Figure 5. (*Left*) An energy level diagram showing the ejection of a (*blue*) neutron by ^{4}H to form the tritium nucleus. (*Right*) the relaxation of ^{4m}H (formed by the fusion of a di-neutron with a deuteron) to ^{4}He. This process is spin allowed. Note that the (*blue*) neutron converts to the (*red*) proton in the absence of a spin flip.

D_2 [36]. Electron capture ($_0n^1p + e^-$) yields the low momentum $_0n_0n$, which is confined in the cathode. The di-neutron does fuse with a proton to yield tritium ($_0n_0n + {}^1p \rightarrow {}^3H$) or with a deuteron to yield helium-4 and excess heat ($_0n_0n + {}^1p_0n \rightarrow {}^{4m}H \rightarrow {}^4He$ + heat) [36].

This is the *Fleishmann Pons Heat Effect*! The ^{4m}H is a very short lived intermediate and is probably a meta-stable nuclear spin state of hydrogen-4 (Fig. 5). The mechanistic details of these LENR reactions, involving the di-neutron, have been recently explained in the *Int. J. Hydrogen Energy* [36].

As expressed by Mark Twain,"The reports of my death are greatly exaggerated;" so it is for the di-neutron. Not only that, but there is evidence that it tends to join with others forming neutron clusters [49,50], and this tendency would be augmented in a PdD matrix. We recognize this as a nuclear metathesis shown in Fig. 6. It is analogous to the Nobel Prize winning chemical metathesis [51].

The observed effects of FPHE, LENR, and low energy transmutations nicely fit into a paradigm that includes at least a transient di-neutron and/or its mutual clusters. Further, this paradigm lacks inconsistencies with the parameters of the standard model and is without the evocation of exotic and unusual forms of matter (e.g. high temperature Fermi or Bose condensates, and quantum entanglements). The di-neutron,under "cold" conditions, fuses with many isotopes(^1H, ^2H, ^{106}Pd, ^{107}Ag, ^{133}Cs, etc.) without having to overcome the e^2/r^2 term in the Lagrangian. It may be time to resurrect the original semantics describing Prof. Fleischmann's discovery as "COLD FUSION."

The fact that the nuclear physics may be different for the di-neutron when constrained in condensed matter is not at all surprising, as this is true even for the ephemeral neutrino. Neutrino flavor oscillations are different (perturbed)when the oscillations occur in condensed matter. This is apparently due to a condensed phase resonance that enhances flavor mixing [52]. Even the rate constant for β-decay, which was once thought to tick as an imperturbable clock, is perturbed when ^7Be is softly constrained in an organic fullerene [53]. Likewise, symmetry breaking resonances in condensed matter renders the quantum field of $_0n_0n$ perturbed.

Finally, the exact quantum physics of a number of empirical observations, for example: (1) the condensed matter

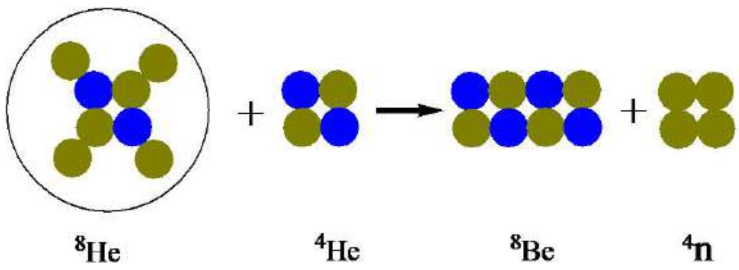

Figure 6. A nuclear metathesis of ^8He with ^4He producing ^8Be and a tetra-neutron, which is probably a resonate state involving (nn + nn) and (^{3} $_0n$ + n). The green spots represent neutrons and the blue spots represent protons.

perturbations upon neutrino oscillation[52], (2) the relativistic electrons in heavy metals [4,6,54], (3) the condensed matter Widom–Larson absorption of electrons [36] and (4) the fundamental nature of the di-neutron [3], has yet to be quantum mechanically resolved. In particular, Hagelstein published some important and interesting quantum inconsistencies in the WL electron capture process (e.g. missing radiation) [55]. However, as the complications involved in computer assisted quantum calculations become more and more untangled, consistency with fundamental quantum theory will undoubtedly be revealed. In the mean time, contemporary attacks on any of the listed (1)–(4) empirically based conclusions have (so far) been based only upon approximation methods of computation.

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