FEMTO-ATOMS AND TRANSMUTATION

A. Meulenberg
National Advanced IPv6 Centre, Universiti Sains Malaysia, 11800 Penang, Malaysia, mules333@gmail.com

Abstract- **The low-energy nuclear-reaction fusion process for a deep-electron orbit femto-hydrogen atom, $H^\#$, with an atomic nucleus yields new isotopes and femto-atoms. The multi-body interaction, strong near-field radiation from tightly bound electrons, and low input energies, make energetic particle emission less common than for normal fusion or neutron-activation processes.**

Index Terms **- Deep-Electron Levels, Femto-atoms, Fusion, Transmutation**

I. INTRODUCTION

In addition to the fusion of hydrogen atoms, the present Lochon [1] and Extended-Lochon Models [2] predict the formation of multi-femtometer size ions and atoms, $H^{\#-}$ or $D^{\#-}$ and $H^\#$ or $D^\#$, and of femto-hydrogen molecules and ions, $H^\#_2$ or $D^\#_2$ and $H^{\#-}_2$ or $D^{\#-}_2$. The number of subsequent fusion products for a femto-hydrogen or femto-deuterium ion or molecule with other nuclei is immense.

Femto ions and atoms are highly mobile in the lattice because of their near-nuclear size. However, the negatively charged ion would not penetrate an atom as readily as they would penetrate a positive ion (they must penetrate the atom’s electron cloud), but would interact with atoms as would a massive electron or an antiproton and eventually fuse (but without the annihilation) or form a femto-molecule. Some of the femto-hydrogen may not fuse with other nuclei. They may form femto-molecules.

Neutral femto-hydrogen molecules may be slowed from fusing by the centrifugal force countering the dipole-dipole Coulomb attraction. They have a finite lifetime that, in matter, would be primarily limited by chance interactions with lattice nuclei. This interaction of $H^\#_2$ or $D^\#_2$, with atomic nuclei would greatly increase the possible LENR products. There will be new selection rules because of this process that may be guidelines rather than rigid rules. The formation and stability of alpha particles, and even neutron-proton pairs, in the product nucleus will be important.

This paper will describe a number of representative transmutations and their energy and radiation release. A unique feature of this model is the selectivity of the femto-hydrogen for radioactive isotopes. The paper finally gives examples of how the low-energy transmutation process works to move isotopes (both stable and unstable) toward stable nuclear configurations.

II. DEEP-ELECTRON ORBITS

The deep-electron energy level predicted by the Klein-Gordon equation is alone and far below the n = 1 levels, so we will call it interchangeably the **n = 0, or ‘nought’, or ‘naught’ orbit or level**. What are some of its properties and problems? Assuming a single electron, bound to a proton, the ‘anomalous’ solution of the K-G equation predicts a binding-energy level of about -507 keV and a characteristic orbit with r_o = 390 fm. However, the high-magnitude binding energy requires a deeper orbit; the effective electron-charge center must be in the low fermi range from the proton.

The deep-orbit solution of the Dirac equations has been shown to be problematic assuming the obviously idealized 1/r dependence of the Coulomb potential, with its point-charge singularity at r = 0. Maly and Va’vra [3] selected a modified Coulomb potential that nuclear-physicists had been using for years. This non-singular potential reflected a charge distribution within the nucleus (rather than a point charge) and still matched the 1/r Coulomb potential beyond the surface of the nucleus. With a non-singular potential, the solution of the relativistic Schrodinger and Dirac equations, which had been rejected by mathematical physicists for over three decades, must now be considered as valid as the normally accepted solutions of the equations.

III. FEMTO-HYDROGEN PATHWAYS

If the deep orbits do exist, and can be occupied, then a new physics discipline with immense practical implications can result. This version of atomic physics opens new pathways to both nuclear physics and femto-chemistry. The nuclear physics opens from a version of muon catalysis. The tight-electron orbit allows a proton (or deuteron) and this electron to be close enough to another nucleus, for long-enough, to initiate fusion reactions. The plural here is used because now, instead of just catalyzing a hydrogen-fusion reaction, new options are open. Proximity to a nucleus by a proton, plus deep-orbit electron(s), leads to at least three-body interactions. The proton-electron pair ($H^\#$, the # indicates a deep-orbit electron and similarly for a deuteron-electron pair, $D^\#$) can be captured by nucleus $^{A}N_{Z}$ to become:

1. $^{A}N_{Z} + H^\# \Rightarrow {}^{A+1}N_{Z}$ + neutrino, if the proton + deep-orbit electron is transformed to a neutron.
2. $^{A}N_{Z} + H^\# \Rightarrow {}^{A+1}N_{Z+1}$ + e, if the deep-orbit electron is ejected (as in the muon case) and the proton is retained in the new nucleus.
3. $^{A}N_{Z} + H^\# \Rightarrow {}^{A}N_{Z-1}$ + p + neutrino, if the deep-orbit electron is retained forming a neutron and the proton is ejected.

4. $^{A}N_{Z}$ + $H^{\#}$ => $^{A}N_{Z}$ $H^{\#}$, if the deep-orbit electron and proton are both retained just outside of the nucleus to form a halo nucleus, a femto-hydride.
5. $^{A}N_{Z}$ + $H^{\#}$ => $^{A}N_{Z}^{\#}$ + p, if the deep-orbit electron alone is retained in orbit to form a femto-atom.

The choice of paths depends on the energy levels and the ‘needs’ of the $^{A}N_{Z}$ nucleus. Pathway 1 requires enough energy to form a neutron from the proton-electron pair. Pathway 2 is for neutron-rich nuclei that gain stability by adding a proton. Pathway 3 is for proton-rich nuclei that gain stability by adding a neutron and subtracting a proton. Pathways 4 and 5 are for nuclei that cannot move to a lower nuclear energy state by internal addition of the proton-electron pair or parts thereof. However, the addition of a femto-atom or deep-orbit electron reduces the total system energy, from the dipole/monopole Coulomb interaction of the atoms, and from reducing the proton-proton repulsion within the nucleus. This selectivity and multiple-path availability provides an energy source, a potential source of stable rare elements, and the means of remediation for radioactive waste products.

Pathways 4 and 5 lead to a new femto-chemistry, to new femto-atoms, and thus to femto-molecules. Presently, pico-second chemistry is of interest using sono-luminescent ‘bubbles’ as the reactors. Some of the femto-atoms and femto-molecules suggested here may be longer lived. There is even evidence of biological systems producing transmutations that may be available by these pathways.

IV. TRANSMUTATION (EXAMPLES)

Just as thermal neutrons in a nuclear reactor are a major source of useful isotopes that do not occur, or no longer exist, naturally, the nought-orbit atoms can also produce useful transmutations. The thermal neutrons can operate only in the manner of pathway 1 (but without a neutrino). A tight-orbit hydrogen atom has all 5 options. As an example of the use of these pathways, it is possible to demonstrate an actual implementation that has claimed some actual results against which we can compare our model.

Figure 1 provides an example of these multiple actions in a system that is of particular interest today. The first claimed sale and delivery of a mega-Watt Low-Energy Nuclear Reaction heat source was announced in late 2011.[1] Other, smaller units are also being advertised.[2] The systems start with metallic nickel powder and creation of significant quantities of stable copper has been claimed. Mention has been made of iron and cobalt by-products as well, with little to no radioactivity beyond the initial startup period. The figure displays the percentage concentration or ½-life of, major decay path for, and energy released in positron emission, or as negative values in beta emission, by isotopes about nickel on the chart.

We will start with the major isotope, ($^{58}Ni_{28}$, red box outline) and identify the pathways available from a local ‘flood’ of femto-hydrogen. The top white box outline represents pathway 2. The bottom white box represents pathway 3. The middle white box represents pathway 1. Pathway 5 is experimentally indistinguishable from pathway 3 unless extremely fine instrumentation is used. Pathway 4 is nearly indistinguishable from pathway 1 except for the lack of a neutrino, again, not an easy observable.

The open arrows indicate transmutation paths induced by a flux of nought-orbit hydrogen. The ‘x’ed arrows indicate paths that are improbable because the product would naturally decay in the opposite manner from the suggested arrows (not all improbable paths are marked). The colored arrows indicate natural radioactive decay paths that would compete with the induced transitions. The availability of options greatly improves the probability of femto-hydrogen attraction to and subsequent transition of radioactive isotopes. The stable isotopes have fewer natural paths along which to transmute. Therefore, they are less likely to attract and fuse with a femto-hydrogen atom (Appendix A). Thus, any natural or process-induced radioactivity dies off as the concentration of nought-orbit hydrogen builds to high levels. This initial radioactivity and subsequent die-off is reported in the type of heat-generation units presently being prepared for commercialization.

There are other differences in the deep-orbit electron pathways from those of presently accepted physics for neutron activation. A most important one is that, because of the high binding energy of the nought orbit, the energy available for the fusion/transmutation reaction may be significantly less (up to 1.5 MeV) than that for thermal-neutron activation. This means that the many nuclei, which would be ‘energized’ by addition of a neutron, would not be as receptive to reaction with a proton plus deep-orbit electron. Thus, instead of creating radioisotopes, the lower-energy fusion process selectively deactivates radioactive nuclei by the above processes (pathways 1 through 3, and even 4 and 5).

V. ENERGETICS AND RADIATION PRODUCTS OF VARIOUS PATHWAYS

The predicted nought orbit electron’s total energy is $E_t = 3.7$ keV, kinetic energy is KE = ~ 1 MeV, potential energy is PE = -1.5 MeV (derived from the binding proton), and its binding energy of $E_b = E_t - m_e c^2 = -507$ keV. With this information, it is possible to look at the energetics of, and radiation from, femto-hydrogen in a nickel lattice (Fig. 1). We look at the possible paths assuming a local, but prolific, source of $H^{\#\#}H$ or of $H^{\#}$ in the lattice assuming only ^{58}Ni for this discussion. We reserve the more probable pathways of the femto-molecule $H^{\#}_{2}$ for later papers. Similarly, we do not discuss here the results for $^{4}He^{\#\#}$ in either a Ni or Pd lattice.

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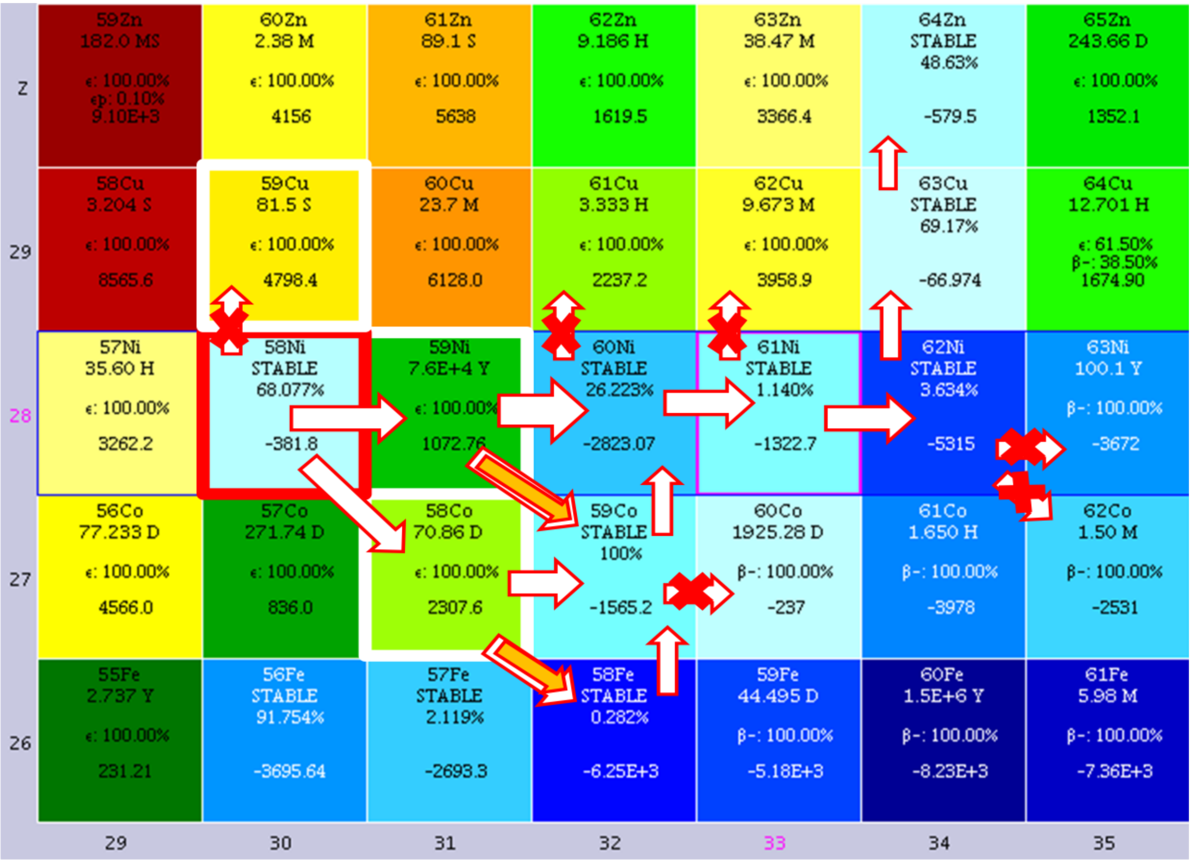
[1] http://www.leonardo-ecat.com/fp/Products/1MW_Plant/index.html

[2] http://www.defkalion-energy.com/products



Z	59Zn 182.0 MS ϵ: 100.00% ϵp: 0.10% 9.10E+3	60Zn 2.38 M ϵ: 100.00% 4156	61Zn 89.1 S ϵ: 100.00% 5638	62Zn 9.186 H ϵ: 100.00% 1619.5	63Zn 38.47 M ϵ: 100.00% 3366.4	64Zn STABLE 48.63% -579.5	65Zn 243.66 D ϵ: 100.00% 1352.1
29	58Cu 3.204 S ϵ: 100.00% 8565.6	59Cu 81.5 S ϵ: 100.00% 4798.4	60Cu 23.7 M ϵ: 100.00% 6128.0	61Cu 3.333 H ϵ: 100.00% 2237.2	62Cu 9.673 M ϵ: 100.00% 3958.9	63Cu STABLE 69.17% -66.974	64Cu 12.701 H ϵ: 61.50% β-: 38.50% 1674.90
28	57Ni 35.60 H ϵ: 100.00% 3262.2	58Ni STABLE 68.077% -381.8	59Ni 7.6E+4 Y ϵ: 100.00% 1072.76	60Ni STABLE 26.223% -2823.07	61Ni STABLE 1.140% -1322.7	62Ni STABLE 3.634% -5315	63Ni 100.1 Y β-: 100.00% -3672
27	56Co 77.233 D ϵ: 100.00% 4566.0	57Co 271.74 D ϵ: 100.00% 836.0	58Co 70.86 D ϵ: 100.00% 2307.6	59Co STABLE 100% -1565.2	60Co 1925.28 D β-: 100.00% -237	61Co 1.650 H β-: 100.00% -3978	62Co 1.50 M β-: 100.00% -2531
26	55Fe 2.737 Y ϵ: 100.00% 231.21	56Fe STABLE 91.754% -3695.64	57Fe STABLE 2.119% -2693.3	58Fe STABLE 0.282% -6.25E+3	59Fe 44.495 D β-: 100.00% -5.18E+3	60Fe 1.5E+6 Y β-: 100.00% -8.23E+3	61Fe 5.98 M β-: 100.00% -7.36E+3
	29	30	31	32	33	34	35

Fig. 1. Chart of Nuclides[1] indicating the femto-hydrogen-induced transmutation paths leading from ^{58}Ni [3]

Assuming >8.7 MeV net gain for each addition of a proton or neutron,[4] a single ^{58}Ni nucleus in the presence of the femto-hydrogen 'field' could transmute 6 times to reach $^{64}Zn_{30}$. This would provide >52 MeV net energy in this chain. However, four of the transmutations may involve forming neutrons with a portion of the gain in nuclear energy. Consequently, a neutrino is formed and escapes with a portion of the excess energy. This would be lost from the heat generated locally in the process.

Most of the chain remains as atomic nickel, so that the lattice is not greatly disturbed.

The process could go through additional paths; but the energy is the same, if it gets to the same final result. Stopping part way, because of insufficient femto-atom flux, will reduce the energy gain per starting Ni atom but not the gain per femto-atom. This first condition would affect the amount of Ni 'used up' over a period of time producing energy. The second condition is related to the production of the femto-atoms and the rate of getting energy from a system.

Two of the nuclides along the probable paths are radioactive, ^{59}Ni and ^{58}Co. It is possible for some of these to decay before they are transmuted to stable isotopes or if they are left over when the system is shut down. In both cases, they will decay by positron emission (ϵ = 100%), which would produce small amounts of energetic and penetrating electron-positron annihilation radiation. The ½ life of this characteristic radiation (511 keV gammas) would be proof of the process. Since ^{59}Ni has a much longer ½ life than does ^{58}Co, even if it is produced in orders of magnitude greater quantities, the 71-day ½-life ^{58}Co decay would be a clear signature.

VI. PATH SELECTION BY A FEMTO-HYDROGEN ATOM

The natural questions arise as to if, why, and how the tight-orbit $H^{\#}$ determines what nucleus to enter and which of the above paths will result from such an intrusion. Possible answers come from both physical and QM causes. Random-walk paths through the nickel lattice and non-selective nuclear encounters would produce a dominance of nickel isotopes, some of which are radioactive. If the $H^{\#}$ has to 'sample' the deep nuclear potential it encounters, then 'selectivity' is too late and any change in interaction volume, $V_n = 4\pi r_n^3$, from such selection would be too small. On the other hand, if selectivity is based on the bound Maxwellian radiation of the nuclear protons and if the interaction drops off as $1/r^6$ for a dipole-dipole interaction (see Appendix B) [4], then, even in the picometer range, the interaction should be significant. If so, the evanescent waves (virtual photons) from the protons in the nuclear well should be able to affect the $H^{\#}$ and alter its path through the lattice, since its

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[3] http://www.nndc.bnl.gov/chart/reColor.jsp?newColor=qec

[4] http://www.nndc.bnl.gov/chart/reColor.jsp?newColor=beda

energy will only be at the lattice temperature.

If this EM radiation field is able to give up energy and lower the total system energy, by drawing the $H^{\#}$ into its source nucleus, then it can increase the interaction cross section by $(r_{EM}/r_n)^3$. The coupling coefficient of the EM interaction between nuclei is small relative to that of a nuclear potential or even that of a Coulomb potential; yet there are no barriers impeding motion of the neutral femto-atom within the lattice and its inertia is only that from the thermal environment. Thus, comparing the near-picometer virtual-photon range to the fermi nuclear size, the capture volume could be increased by > 7 orders of magnitude. Since the femto-atom's motion through the lattice is non-linear, the interaction volume, not its cross-section, is important.

How does this hypothesis work out in practice? The 'preferred' paths based on Table 1 were identified based on the known decay modes of both starting and product nuclides where radioactivity is present. If the starting nuclide is a positron emitter, it is unlikely that it will accept a proton from the femto-hydrogen. On the other hand, it would like the DDL electron from that entity. If the ending nuclide is a beta emitter, it is an unlikely goal for accepting the electron of the femto-atom (accept as a portion of a halo nucleon). Anything leading to a stable nuclide would be considered a preferred path. Anything leading from a stable nuclide is considered a low probability transition. It will only occur when the concentrations of the femto-hydrogen and/or the stable nuclide are high.

TABLE 1

NUCLIDE + FEMTO-HYDROGEN TRANSITIONS AND ENERGIES.

Starting Nuclide	Product Nuclide and Q	
58Ni(68.1%)+ H#	-> 59Ni	+7.717 MeV
58Ni(68.1%)+ H	-> 59Cu	+2.919 MeV
59Co(100%)+ H#	-> 60Co	+6.210 MeV
59Co(100%)+ 1H	-> 60Ni(26.2%)	+9.032 MeV
60Ni(26.2%)+ H#	-> 61Ni(1.14%)	+6.538 MeV
60Ni(26.2%)+ 1H	-> 61Cu	+4.300 MeV
61Ni(1.14%)+ H#	-> 62Ni(3.64%)	+9.314 MeV
61Ni(1.14%)+ 1H	-> 62Cu	+5.355 MeV
62Ni(3.64%)+ H#	-> 63Ni	+5.555 MeV
62Ni(3.64%)+ 1H	-> 63Cu(69.2%)	+5.622 MeV
64Ni(0.93%)+ H#	-> 65Ni	+4.816 MeV
64Ni(0.93%)+ 1H	-> 65Cu(30.8%)	+6.954 MeV
63Cu(69.2%)+ H#	-> 64Cu	+6.634 MeV
63Cu(69.2%)+ 1H	-> 64Zn(48.6%)	+7.213 MeV
65Cu(30.8%)+ H#	-> 66Cu	+5.784 MeV
65Cu(30.8%)+ 1H	-> 66Zn(27.9%)	+8.425 MeV
64Zn(48.6%)+ H#	-> 65Zn	+6.697 MeV
64Zn(48.6%)+ 1H	-> 65Ga	+3.443 MeV

Table 1 gives some examples of the energetics of many of the transitions examined in Fig. 1. The table values are based on an earlier estimate of the femto-hydrogen properties where the electron energy was 0.5 MeV lower and the proton mass was 0.5 MeV higher. However, the binding energy was the same. The table does not include radioactive starting nuclides or electron-capture transitions. Nevertheless, it does indicate preferred paths in agreement with those identified in the figure.

The table shows pairs of transitions. In each pair, the starting nuclide is combined with either an $H^{\#}$ or an H. These choices correspond to the equivalent of adding a neutron (a proton and nought-orbit electron) or a proton from the femto-hydrogen. With only a single exception, the preferred path is unambiguous. The exception is that of ^{62}Ni. The choice of continuing along the Ni path or changing to copper is not clear-cut. However, continuation along the Ni path beyond ^{64}Ni (not shown in the figure) appears closed by the energetics. The stable ^{65}Cu nuclide gives a strong preference over the short-lived ^{65}Ni branch in the table.

The QM answer to the preferential interaction of radioisotopes for the femto-hydrogen comes from the small size of the nucleon wave functions (in the multi-fm range) versus that of the EM portion of the nuclear protons and the relativistic deep-orbit electron(s) (in the multi-hundred fm range). The difference between the femto-atom case and the normal atomic interaction is in the electron orbit. If the internuclear separation is larger than the atomic-electron orbitals, the dipole-dipole interaction is stronger than the 'screened' nuclear Coulomb repulsion. For smaller separations, the screening is inadequate and the repulsion dominates and keeps atoms apart. This explanation is simply described in terms of electrostatics. For the femto-atom case, the screening is complete down to nearly nuclear dimensions, so that electrostatics play little role beyond the dipole-dipole attraction. However, with the strong acceleration experienced by deep-orbit electron(s) and by excited-state protons, the EM fields now becomes more important than even a dipole-monopole interaction. To my knowledge, this contribution to the QM wave function(s) has never been recognized or applied in the past.

Assuming the larger EM-field interaction volume, how does the potential for radioactive decay affect the nuclear evanescent waves? (See Appendix A.) Since the nuclear potential can be approximated by a square well, the excited states will have higher frequencies than the filled states. They will radiate more and stronger EM-fields at higher frequencies and therefore at higher nuclear energies. Any energy transfer, which could lower the system energy by bringing the bodies closer together, would provide an attraction between nucleus and femto-atom. Thus, excited nuclei, or those with excess kinetic energy, would have a stronger EM field and therefore a larger capture cross-section.

The force driving this action is expressed simply as $\mathbf{F} = -dV/dr$, where V is the potential energy of the nucleus at distance r from the femto-atom. The potential energy is the ability to do work. Radioisotopes have excess energy relative to their ground state. Work that can be done includes moving the femto-hydrogen closer to the radioactive nucleus. This pathway to lower energy levels does not only compete with gamma transitions, it interferes with them and therefore suppresses them by altering the resonant frequencies.

While the hydrogen or femto-hydrogen nucleus is not radioactive, the combination with another femto-hydrogen, as a molecule, is a lower energy state; therefore, work can be done in bringing them closer together. Thus, there will be a significant attractive potential (and force) between these atoms because of their proximity relative to that of normal molecular atoms.

In (1a), the lower probability solar fusion p-e-p reaction[5] is shown with the deuteron and neutrino fusion result along with the mass defect energy, Q. By comparison, (1b) shows production of a femto-hydrogen molecule. I do not believe that the similarity in Q values is a coincidence. The 'less than' symbol is used in (1b) because, while the potential energy loss in bringing the electron to the DDL is ~1.5 MeV, some of that energy is translated into kinetic energy of the protons (~ 1 MeV is added to the deep-orbit-electron kinetic energy and mass).

$$p + e + p = d + \nu \qquad Q = 1.44\ \text{MeV} \tag{1a}$$

$$p + e + p = H_2^{\#} \qquad Q < 1.5\ \text{MeV} \tag{1b}$$

The reason to mention this is that a deuteron is considered a 'halo' nucleus.[6] The neutron and proton wave functions do not have strong overlap. Therefore, they do not spend much time in the nuclear potential well that they make when close to each other. The halo nucleus is not, but could be, considered a femto-molecule. Seen as a femto-molecule, the neutron and femto-hydrogen could be names for the two molecular s-orbitals that are separated in energy by the quadratic-Stark effect. The Stark effect is the splitting of energy levels by an external electric field (such as that provided by a nearby nucleus).[7]

For the case where a proton has two deep-orbit electrons bound to it, the pair is considered a boson (a lochon). As such, the Klein-Gordon equation provides the proper mathematical model and this then becomes a nought orbit with the electrons strongly coupled by their magnetic moments as well as by the proton's Coulomb field. The difference in isotopic transition paths induced by the femto-hydrogen atom versus that of the negative ion is very small in the case described in Fig. 1. The major difference is that ^{58}Fe has a higher probability of being created by the ion with its two electrons. It can be created by a flood of the atoms in a 2-step process; but the negative femto-ion can do it with a single 'hit'. A major difference in the femto-ion vs the femto-atom interactions is the charge. The negative ion has long-range attraction (100s of fm) to any nucleus. Thus, the selective attraction to radio-active nuclides is no longer a dominant feature.

We have shown a simple example of nought-orbit (or femto-hydrogen) induced transmutation. It gets more complicated when deuterium (as $D^{\#}$) or femto-molecular hydrogen (as $H^{\#\#}_2$) is considered. With femto-helium (e.g., $^4He^{\#\#}$ resulting from fusion of deuterium atoms), the changes in atomic number can be ±2 and changes in atomic mass can be up to 4 (with multiples and variations thereof). Thus, the breadth of nuclear-waste remediation gets broader very rapidly. While heavier isotopes of H and He are expected to be useful, nothing with more than a pair of electrons is expected to provide a useful nought orbit.

Heavier halo nuclei are not uncommon; however, in the present model, they would be created by interactions with femto-hydrogen, either as direct femto-molecular formation or as a by-product of a nuclear reaction of the parent nucleus with a femto-hydrogen or helium atom or ion.

VII. CONCLUSIONS

Transmutation associated with cold-fusion results was a surprise. However, on closely examining the consequences of the deep-orbit electrons postulated to provide the low-energy fusion of repulsive hydrogen nuclei, the possibility of transmutation became clear. The discovery of relativistic deep-electron orbits for both the Klein-Gordon and Dirac equations confirmed the cold-fusion predictions of deep electrons involved in the process.

These orbits, long-lived relative to the multiple pass-by electron transits originally postulated, greatly amplify the numbers and types of transmutations available. The creation of low kinetic-energy neutral femto-atoms and femto-molecules allow a long-range selective attraction to radio-active nuclei and thereby provides a means of distributing these newly created transmutants far from their originating site.

One difference between the system of a 'radioactive nucleus and a femto-atom' relative to the system of a 'non-radioactive nucleus and the femto-atom' has to do with the amount of energy released by the fusion of the two. Another difference between these systems is the excitation level(s) of the components causing the evanescent wave(s) that serve as an attractant to the femto-atoms. A third difference is in the 'orbital' frequency of the excited nucleon(s) relative to that of the ground-state nucleons. A fourth difference involves the angular momentum of the different states. These differences are generally related, but not necessarily so.

The second and third differences lead to a most important feature of the model: selectivity of nuclei by the femto-particles. This possibility means that these femto-atoms can be used to produce energy from nuclear transmutations with a minimum of radioactivity resulting. It also gives the possibility for nuclear-waste remediation and, more important for the future, it allows us to tailor elements and isotopes for specific applications.

In addition to having a limitless source of inexpensive, non-polluting energy, humanity will never run short of rare-earth metals.

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[5] http://en.wikipedia.org/wiki/Proton-proton_chain#The_pep_reaction

[6] http://en.wikipedia.org/wiki/Halo_nucleus

[7] http://en.wikipedia.org/wiki/Stark_effect#Second_order

Appendix A: Evanescent-Wave Coupling Between Neutral Nuclei

Evanescent waves (or virtual particles) convey no energy unless there is an absorber within its range. What is an absorber? It could be something as simple as a two energy-level system (such as used in Ref. 4).

However, just as there are simple coupled oscillators (such as the atoms in the reference), there are also more complex systems. In the present system, the excited nucleus (one able to decay radioactively) is an obvious 2-level system. The second oscillator is not a 2-level system. The neutral femto atom has a fixed final state, fusion with the excited nucleus. However, its excited state is related to the distance between it and the radioactive nucleus. Even without knowing the coupling coefficient, we can still look at the potential for doing work, V.

Assume any position-dependent potential, $V(r_{ij})$. The force between two 'actors' (i and j) creating this potential is related to the potential, $\mathbf{F}_{ij} = -dV(r_{ij})/dr$. There is an energy related to this potential. Thus, the second excited-energy level is not a fixed energy; it is a variable, dependent on r. In addition, the system is not strictly an oscillator; but it could be. The major point to be made is that if there is no possibility of a net energy change, it is a conservative system and the interaction is greatly reduced (but not necessarily zero).

The exchange of virtual photons between two atoms in the ground state is an example of a low-impact interaction. Pion-exchange between a neutron and proton is an example of a high-impact interaction. Both are interactions between 'identical' particles. However, the coupling mechanism between them (related to the virtual energy exchanged) is quite different. This also affects the range of the interaction. However, the 2-level oscillators in the identical particles cases are the energy related to the spacing between the particles.

The two <u>distinct</u> energy levels are related in time, before and after, rather than in space. The energy difference between the two cases presented is fractions of an eV versus > 100 MeV. In the latter case, the cause and shape of the nuclear potential is unknown. Nevertheless, use of the internal resonance associated with a virtual-exchange particle, the pion, predicts very well the effective potential between nucleons. The potential shows an ability to do work, to move nucleons and to accelerate them to high energies (by some means, even if unknown).

The system that we are studying is different, but similar enough to provide a model. We are not studying identical particles; neither the targets nor the 'projectiles' are identical. Therefore, we have sacrificed two major components of a resonant-energy transfer. On the other hand, we know more about the nature of our proposed energy-exchange fields, the evanescent waves of the bound protons and electrons. These are the Maxwellian near-field EM wave of an oscillating and/or rotating electric dipole.

Appendix B: Near-Field Dipole-Dipole Electromagnetic Coupling [4]

For computation, we shall confine ourselves to two adjacent systems (1 & 2), each with two-levels (n & p and m & o). We assume that $E_{pn}(p \to n)$ is larger than $E_{om}(o \to m)$, i.e., the excited-state proton has more energy to lose than the nought-orbit electron can gain. Averaging over all polarizations and angles leads to the effective interaction between two randomly oriented dipoles at a distance R apart in free space. Then, the near-field interaction can be recast as

$$U_{eg}^{NZ}(R) = -\frac{2}{3}\frac{1}{R^6}\frac{\left|\mu_{mo}(2)\right|^2\left|\mu_{np}(1)\right|^2}{\left(\left|E_{np}(1)\right| - \left|E_{om}(2)\right|\right) = \Delta E_{12}} \qquad \text{(B–1)}$$

where ΔE_{12}, is a positive number and μ_{ij} are the matrix elements of the transition-dipole moments. In the near-field region, the dipoles are separated by much less than a wavelength at the energy of interest, $R << \lambda$. The important features of (B-1) are the R^{-6} dependence and the resonance established between the two energy transitions.

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