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Research Article

Femto-atoms and Transmutation

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Abstract

The low-energy nuclear-reaction (LENR) 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.
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1. Introduction

In addition to the fusion of hydrogen atoms, the present Lochon [1] and Extended-Lochon Models [2] are consistent with the formation of multi-femto-meter 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 $D_2^{\#+}$. Femto-atoms, with very high electron-binding energies, have been proposed for over 50 years [3,4]. They are based on a solution of the standard Schrodinger, Klein–Gordon, and Dirac equations. This particular solution has been rejected by mathematical physicists for nearly as many years because, assuming a $1/r$ Coulomb potential, it is singular at $r = 0$. Since, a $1/r$ potential implies that all of the energy of the universe is tied up in a single electron, a real, non-singular, potential must be used. Once a realistic potential is used, such as those used in nuclear physics, the argument against this 'anomalous' solution fails and legitimate deep-Dirac level (DDL) electron orbitals emerge with binding energies on the order of 500 keV [5].

The 500 keV energy levels have not been observed for several reasons. The primary one is that the population is extremely low [6]. If these levels were as stable as the atomic orbitals, the number of DDL electrons would only be on the order of parts-per-billion relative to the atomic s orbitals. However, with electron orbital radii in the fermi range, the lifetime of femto-hydrogen in matter could be less than picoseconds. In this case, the ratio of femto-hydrogen atoms to normal ones might be 10^{-20} to one. This would make detection, via photon absorption (e.g., from annihilation radiation at 511 keV), very difficult.

Detection of radiation from the decay of an electron in an atomic orbital to the DDL would be similarly problematic. The difference in energies between these levels is ~5 orders of magnitude. More problematic is the fact that electrons

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in the H ground-state, and below, do not have sufficient angular momentum with which to form photons. This means that such transitions are highly forbidden. Thus, the transition probability is another 6–8 orders of magnitude less likely than a similar transition with sufficient angular momentum. Only if the atoms can interact inelastically with matter can their electrons decay to the lower levels.

Once formed, the number of subsequent fusion products for a femto-hydrogen or femto-deuterium ion or molecule with other nuclei is immense. This reduces the femto-atom population much faster than would reexcitation of DDL electrons to the atomic levels. Of perhaps greatest importance in this regard is the interaction of two femto-hydrogen atoms. This is the most probable interaction because the population of the DDLs is primarily a result of phonon-induced H–H or D–D interactions in the lattice during which the paired protons with DDL electron(s) will greatly enhance p–e–p or p–e–e–p fusion. If the two converging nuclei have too much angular momentum to fuse immediately, it is proposed that they will form a meta-stable femto-molecule with the deep-orbit electrons binding them. At even higher angular momentum levels, the protons can separate and the spin-coupled electron pair may go with one or the other. This would produce a negative femto-hydrogen ion along with a proton.

Femto-hydrogen molecules may be slowed from self-fusing by the centrifugal force countering the dipole–dipole Coulomb attraction of the composite femto-atoms and the strong interaction of their nucleons. They have a finite lifetime that, in matter, would be primarily limited by chance interactions with lattice nuclei. Femto ions, atoms, and molecules are highly mobile in the lattice because of their near-nuclear size. The interaction of $H_2^{\#}$or $D_2^{\#}$, with atomic nuclei of the lattice 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. However, some of the femto-hydrogen may not fuse with other nuclei. They may form femto-molecular hydrides. The negative femto-hydrogen ion would also do that readily.

This paper will describe a number of representative transmutations in the NiH system 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.

2. 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 [7]. 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 [8].

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 [5] selected a modified Coulomb potential that nuclear hysicists 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 five decades, must now be considered as having low population [6], but being as valid [4] as the normally accepted solutions of the equations.

3. Femto-hydrogen Transmutation 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 to form a neutron from an existing proton and the incident proton is ejected.
(4) ${}^{A}N_{Z} + H^{\#} \rightarrow {}^{A}N_{Z}H^{\#}$ if the deep-orbit electron and proton are both retained just outside of the nucleus to form a halo nucleus, a femto-hydride.
(5) ${}^{A}N_{Z} + H^{\#} \rightarrow {}^{A}N_{Z}^{\#} + p$ 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.

4. 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 five 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.[a] Other, smaller units are also being advertised.[b] 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

[a] http://www.leonardo-ecat.com/fp/Products/1MW_Plant/index.html
[b] http://www.defkalion-energy.com/products

radioactivity beyond the initial startup period. The figure displays the percentage concentration or half-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 1–3, and even 4 and 5).

5. 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 $=\sim 1$ 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 $^4He^{\#\#}$ in either a Ni or Pd lattice.

Assuming >8.7 MeV net gain for each addition of a proton or neutron,[c] 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. There are intermediate paths possible for transmutation from one Ni isotope to the next. Nevertheless, they are improbable and therefore marked with a red X in Fig. 1. An example of an improbable path is ^{58}Ni to ^{59}Cu via proton capture. It is going against the natural decay path of the ^{59}Cu, which is to emit a positron, not to capture a proton. The proton + electron weak interaction to a neutron is energetically more probable (Table 1); however, it may not be the preferred path, since the weak interaction to form a neutron from the $H^{\#}$ is much slower than the capture of an electron alone (to go to ^{59}Co).

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

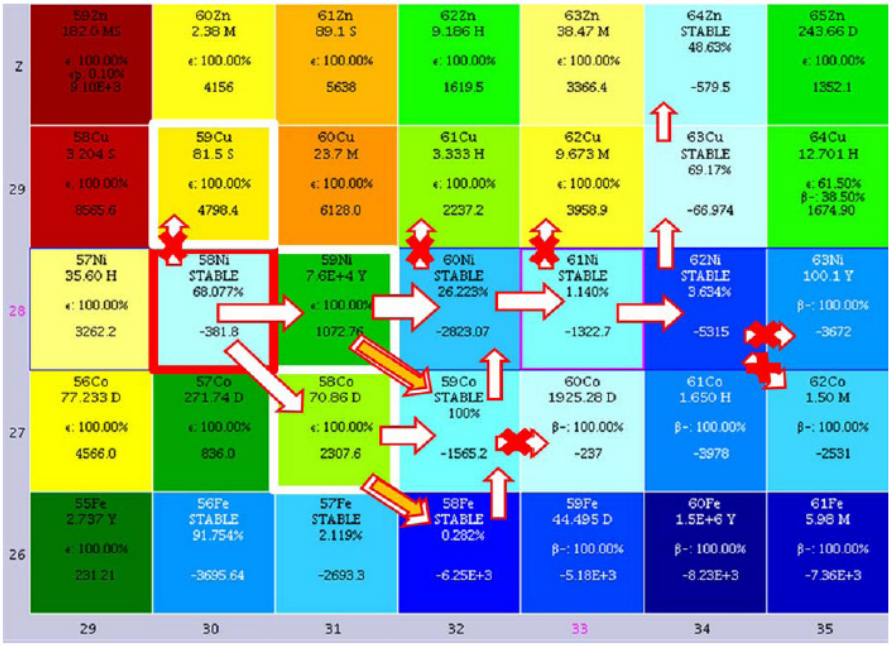

Figure 1. Chart of nuclides (see http://www.leonardo-ecat.com/fp/Products/1MW_Plant/index.html) indicating the femto-hydrogen-induced transmutation paths leading from ^{58}Ni (http://www.nndc.bnl.gov/chart/reColor.jsp?newColor=qec).

Although the process could go through additional paths, the total energy produced 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, e.g., transmutation from Ni to Co or Fe and back to Ni, would affect the amount of Ni 'used up' over a given period of time producing energy. The second condition is related to the production of the femto-atoms and therefore the rate of getting energy from a system. It could also alter the chemical structure of the cold-fusion source region.

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 ($\epsilon = 100\%$), which would produce small amounts of energetic and penetrating electron–positron annihilation radiation. The half life of this characteristic radiation (511 keV gammas) would be proof of the process. Since ^{59}Ni has a much longer half life than does^{58}Co, even if it is produced in orders of magnitude greater quantities, the 71-day half life of ^{58}Co decay could be a clear signature.

6. 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 [9] of the nuclear protons and if the interaction drops off as $1/r^6$ for a dipole-dipole interaction (see Appendix B), then, even in the pico-meter 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 the femto-atom kinetic 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 $k_{\mathrm{EM}}(r_{\mathrm{EM}}/r_n)^3$. The coupling coefficient of the EM interaction, k_{EM}, 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. Since the femto-atom's motion through the lattice is non-linear, the interaction volume, not its cross-section, is important. Thus, comparing the near-picometer virtual-photon range to the fermi nuclear size, the capture volume could be increased by > 7 orders of magnitude.

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 (except 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 lower probability transition. It will only occur when the concentrations of the femto-hydrogen and/or the stable nuclide are high.

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 starting nuclides that are radioactive or electron-capture transitions. Nevertheless, it does indicate preferred paths in agreement with those marked in Fig. 1.

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. Based on energetic alone, the choice of continuing along the Ni path to a long-lived isotope, ^{63}Ni, or changing to a stable copper isotope, ^{63}Cu, 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 inter-nuclear 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 [9]. 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

Table 1. Nuclide and femto-hydrogen transitions and energies

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

states will have higher frequencies than the filled states. Electrons in excited states 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 $F = -\mathrm{d}V/\mathrm{d}r$, 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 time spent at 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 Eq. (1), the lower probability solar fusion p–e–p reaction[d] is shown with the deuteron and neutrino fusion result along with the mass defect energy, Q. By comparison, Eq. (2) 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 Eq. (2) because, while the potential energy loss in bringing the electron to the DDL is $\sim$ 1.5 MeV, some of that energy is translated into kinetic energy of the protons ($\sim$ 1 MeV is added to the deep-orbit-electron kinetic energy and mass).

$$\mathrm{p} + \mathrm{e} + \mathrm{p} = \mathrm{d} + \nu, \quad Q = 1.44\ \mathrm{MeV}, \tag{1}$$

$$\mathrm{p} + \mathrm{e} + \mathrm{p} = \mathrm{H}_2^{\#}, \quad Q < 1.5\ \mathrm{MeV}. \tag{2}$$

The reason to mention this is that a deuteron is considered to be a 'halo' nucleus.[e] 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).[f]

For the case where a proton has two deep-orbit electrons bound to it, the pair is considered a boson (a lochon, or local charged boson). 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 femto-hydrogen 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 femto 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 $\mathrm{D}^{\#}$) or femto-molecular hydrogen (as $\mathrm{H}_2^{\#\#}$) is considered. With femto-helium (e.g., $^4\mathrm{He}^{\#\#}$ resulting from fusion of two 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.

7. 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

[d] http://en.wikipedia.org/wiki/Proton-proton_chain#The_pep_reaction
[e] http://en.wikipedia.org/wiki/Halo_nucleus
[f] http://en.wikipedia.org/wiki/Stark_effect#Second_order

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 allows 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 from cold fusion, humanity will never run short of rare-earth metals.

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 [10]).

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, i.e., 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 V for doing work.

Assume any position-dependent potential, $V(r_{ij})$. The force between two 'actors' (i and j) creating this potential is related to the potential, $F_{ij} = -\mathrm{d}V(r_{ij})/\mathrm{d}r$. 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 distinct 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 [8–10]. 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 [10]

For computation, we shall confine ourselves to two adjacent systems (1 and 2), each with two-levels (n & p and m and o). We assume that $E_{\rm pn}$ (p $\rightarrow$ n) is larger than $E_{\rm om}$ (o $\rightarrow$ 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

$$U_{\rm eg}^{\rm NZ}(R) \;=\; -\,\frac{2}{3}\,\frac{1}{R^6}\,\frac{|\mu_{\rm mo}(2)|^2\;\left|\mu_{\rm np}(1)\right|^2}{\left(\left|E_{\rm np}(1)\right| \;-\; |E_{\rm om}(2)|\right) \;=\; \Delta E_{12}}, \tag{B.1}$$

where ΔE_{12} is a positive number and μ_{ij} are the matrix elements of the transition-dipole moments.

It is important to note that it could be the frequencies that are more important for this interaction than are the energies. In normal transitions, the bound-electron energy is converted to and from photons (with $E = h\nu$) so that the frequencies are related to the change in energy of the states involved. The $\Delta E_{12} = 0$ satisfies energy conservation and establishes the balances between photon energies and bound-electron levels,

Because of the proximity of the radioactive nuclide and the femto-hydrogern (fractions of a nanometer), the energy transfer may not be via photonic transition. Furthermore, in the presence of the strongly varying local electric fields, the DDL electrons and nearby nuclei may not have well-defined energy levels. Energy must still be conserved, but resonance is key: $\nu_1 = \sim \nu_2$ and $\Delta\nu_{12} = \sim 0$. Resonance can stimulate emission of energy from an excited state. Since the two oscillators, the excited nucleon and the DDL electron, do not have the same mass, $\Delta\nu_{12} = \sim 0$ does not imply that$\Delta E_{12} = 0$ or that E_1 is the same as E_2. It implies that the frequency of the excited state (nucleon) is the same as that of the DDL electron which electric field would be stimulating it. The equation change necessary to adapt to direct stimulation, rather than to photonic stimulation, is shown in Eq. (B.2). Since the frequencies are of 'bodies' rather than photons, the use of Planck's h to provide the energy base may not be appropriate. A new normalization constant might have to be determined.

$$U_{\rm eg}^{\rm NZ}(R) \;=\; -\,\frac{2}{3}\,\frac{1}{R^6}\,\frac{|\mu_{\rm mo}(2)|^2\;\left|\mu_{\rm np}(1)\right|^2}{h\left(\left|\nu_{\rm p}(1)\right| \;-\; |\nu_{\rm m}(2)|\right) \;=\; \Delta h\nu_{12}}. \tag{B.2}$$

The important features of (B.2) are the R^{-6}dependence and the resonance established between frequencies of the two oscillators (i.e., $\Delta\nu_{12}$ is small).

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