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Research Article

Femto-Helium and PdD Transmutation

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Abstract

Extensive evidence exists for cold fusion to produce transmutation products as well as excess heat. This paper deals with the palladium–deuteride (PdD) structure that is generally modeled with a deuterium-to-helium (D + D $\Rightarrow$ ^{4}He) cold-fusion process. How this process results in transmutation is based on the extended-lochon model that predicts deep-orbit electrons that are tightly bound to the ^{4}He nucleus and thus make the equivalent of a neutralized alpha particle. This model is compared with the NiH system (H + H $\Rightarrow$ D, $H_2^{\#\#}$, or 2H$^{\#}$) described earlier and distinguishes long-range from short-range transmutation (distance from the fusion site) as well as the relative excess energies from fusion vs. transmutation. The model predicts the probable transmutation process(es) and products in the palladium system and explains other observed results of cold-fusion experiments.

Keywords: Femto-atoms, Femto-molecules, Deep-Dirac levels, Neutral-alpha, Selective fusion

1. Introduction

Cold fusion, CF, is distinguished from the conventionally accepted D–D fusion process by production of ^{4}He rather than of fragmentation products (protons, neutrons, tritium, and ^{3}He). Therefore, CF (with deuterium) is most commonly modeled with a D + D$\Rightarrow$^{4}He process. The present Lochon [1] and Extended-Lochon Models [2] of CF predict deep-atomic electrons as a mediator for cold fusion. In particular, deep-Dirac levels (DDLs are atomic levels with relativistic electrons having femtometer orbits and a binding energy $>$500 keV), as predicted by relativistic quantum mechanics and the Dirac equations [3], can be populated in this pre-fusion process. The extended-lochon model states that this electron energy (high-binding and kinetic) comes from the potential energy (mass) of the proton binding it. The energy release, associated with electron decay from ground-state-atomic to deep-Dirac levels, cannot come from normal dipole radiation because there is insufficient angular momentum to form photons. Low-probability second-order effects, such as the double-photon process or interaction with lattice electrons and phonons, must be expected instead. Low electron-transition probability to the DDLs is proposed as the limiting factor in cold fusion processes.

In the deuterium system, tunneling through the D-?-D Coulomb barrier, but beneath the ^{4}He fragmentation levels [2], is suppressed because there are no resonant nuclear states available to assist in the process at the energies involved. When fusion does occur, the deuterons (or their component parts) are in an excited condition, but not at any resonant levels.

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Therefore, while EM fields can be produced by the accelerating protons and by the tightly bound electrons, no specific-energy gamma radiation results from any de-excitation. Furthermore, since neither the protons nor the electrons have any quantized angular momentum ($\ell = 0$) or any lower energy states (and the ground state has zero angular momentum), EM emission is further limited to the low-probability double-photon emission (zero-to-zero angular-momentum-state transitions are highly forbidden). This low-probability radiation mode can provide the necessary angular momentum for photons and still conserve the zero angular momentum of the system. With normal decay paths blocked, alternative (perhaps also forbidden) pathways, which are generally not considered, must be evaluated [4].

These limitations to the dissipation of nuclear energy greatly increase the time needed for an excited ^{4}He* nucleus to reach the ground state. However, the presence of the DDL electrons (forming a ^{4}He$^{\#\#}$ atom, with each superscript # representing a DDL electron) provides the best path for this decay [4]. There are consequences of both this pathway and the longer time required for it to dissipate the excess nuclear energy from the fusion process.

During the ^{4}He$^{\#\#}$ decay process, and before the electrons are ejected with the remaining nuclear energy, the composite structure of two protons, two neutrons, and two DDL electrons is an excited 'femto-helium' atom [5,6]. Because of its small DDL orbital radii, the femto-helium atom is only slightly larger than an alpha particle. While discussing its nuclear interactions with lattice nuclei, we will call this small, neutral, body a 'neutral alpha'. Its interactions will be like a super-low-energy, charge-free, alpha collision, with the additional aspects of the DDL electrons, the 'loosely bound' nucleons, and the remaining nuclear energy of the decaying ^{4}He* nucleus. Alternatively, it can be considered to be an excited multi-femtometer size 'atom', ^{4}He$^{\#\#}$, that decays slowly to the ^{4}He ground state unless/until fusion processes with adjacent nuclei either absorb or release its energy or component parts. The decay to ground state has been addressed earlier [4,6] and is perhaps the most probable scenario. The fusion products, formed with nearby lattice nuclei, would be a clear signal of any CF nuclear process(es) and their nature. That interaction with lattice nuclei and its consequences is the topic of this paper.

The number of subsequent fusion products for such a neutral-alpha interaction with lattice nuclei is disproportionately large relative to that from neutron activation or even transmutation from femto-hydrogen [7]. This 'option' of multiple transmutation products greatly increases the total interaction cross section with nuclei near to the CF source and perhaps the energy released to the lattice. The large energy input to a lattice nucleus (i.e., the addition of four nucleons) also makes nuclear fission quite likely. The evidence for induced-fission reactions (e.g., some of Mizuno's work [8]) as a major contributor to excess energy of CF reactions in PdD and its consequences will be addressed in a future paper.

Femto-ions, -atoms, and -molecules are highly mobile in the lattice because of their near-nuclear size. On the other hand, neutral alphas have a finite lifetime that, in matter, limits the possible range from its source by more than just the effects of chance interactions with lattice nuclei. The relatively short range of these neutral alphas provides a couple of unique signatures for the PdD system relative to the Ni-H system.

A number of representative transmutations, with their energy and radiation release, are described to illustrate the neutral-alpha model. A feature of the Femto-hydrogen model is its selectivity for radioactive isotopes. It is expected that to a lesser degree (because of lower mobility) the neutral-alpha will display a similar selectivity. A discussion of the applicability of this model to the PdD system will address the proposed transmutation spatial 'profile' and its comparison with the NiH system.

2. Differences between NiH and PdD Systems ($H_2^{\#\#}$ vs. ^{4}He$^{\#\#}$)

Ni-based systems appear to produce more heat when loaded with H than with D. Pd-based systems appear to produce more heat when loaded with D than with H. Why?

To first order:

(1) The p+e+p $\Rightarrow$ D + neutrino fusion reaction [9] gives much less excess energy (1.44 MeV) than does the

D+D$\Rightarrow^4$He (+ up to 24 MeV excess) reaction.

   (a) Being a 3-body reaction, the p–e–p fusion is less common in the sun than the 2-body p–p reaction.
   (b) Being a weak interaction, neither the p–e–p nor the p–p fusion reactions are very probable under most circumstances.
   (c) Under the high-density conditions of a collapsing star, both reactions become many orders of magnitude more rapid.

(2) Other options include cold fusion processes (where # indicates a DDL electron and the deep-orbit electron places the protons and electron(s) very close together – as in 1.c.):
   (a) H+H $\Rightarrow$ 2 $H^{\#}$, or $H_2^{\#+}$ + e, or $H_2^{\#\#}$
   (b) D+D $\Rightarrow$ 2 $D^{\#}$ ($D_2^{\#\#}$, $D_2^{\#+}$, or $^4He^{\#+}$and $^4He^{\#\#}$ are probably very short-lived)
   (c) all cold fusion reactions are unlikely unless conditions are right.

(3) Transmutation from interaction of a femto-atom with a lattice atom:
   (a) $H^{\#}$ produces 6–8 MeV (assuming addition of a nucleon),
   (b) 2 $H^{\#}$, or $H_2^{\#+}$, or $D^{\#}$ produces 12–16 MeV (assuming addition of two nucleons),
   (c) $^4He^{\#\#}$ produces up to 30 MeV (assuming addition of four nucleons at 6–8 MeV per nucleon plus the nuclear energy dissipated by the deuterons prior to collision with a heavier nucleus). However, a stable alpha configuration within a nucleus may reduce the average individual energy-gain per added nucleon.
   (d) Fission induced by these interactions could provide even more excess nuclear energy.

(4) Palladium plus $^4He^{\#\#}$ has more options to cause transmutation than does Pd + $H_2^{\#}$, or Pd + $D^{\#}$, or Pd + $H^{\#}$.
(5) Experimentally, $^4He^{\#\#}$ (hence $D^{\#}$+$D^{\#}$) produces less excess heat in Ni than in Pd. This could relate to a difference in actual fusion rates and/or to the fact that induced fission of the heavier lattice nuclei in the PdD CF reactions could produce more excess energy.
(6) $H^{\#}$ (hence H+H) produces less excess heat in Pd than in Ni. This could relate to actual fusion rates being lower in the larger lattice and/or to the lower average energy from adding nucleons to the heavier lattice nuclei (having fewer transmutation options than the $^4He^{\#\#}$ 'neutral alpha' (see below) may mean less average energy per fusion.
(7) $D^{\#}$+ $D^{\#}$ should always be the dominant heat generator, because the excess energy of the D+D $\Rightarrow^4$He reaction is generally greater than other combinations of transmutations available by the proton or neutron addition to a nucleus.

However, some 'second-order' effects may dominate.

3. Second-order Effects

(1) In the lochon model, matched-electron pairing effects may be critical [5]
(2) In the linear-molecule model [10], strong phonon effects depend on single-species linear sub-lattices
(3) Both above models depend on deep-electrons to produce fusion and femto-molecules. Filling of the DDLs depends on oscillation amplitude of the hydrons (protons, deuterons, or tritons) involved as well as their proximity. Both effects are dependent on symmetry of the species.
(4) Phonon effects may be limited by the asymmetry of the deuteron electric dipole-moment orientation and its center of mass. This can affect oscillation amplitudes and the effect may be stronger in nickel-based than in palladium-based systems. Thus, mixed-species operation (i.e., D+H and p+n (d vs. p only)) is probably less efficient in CF than is any pure-species operation.

3.1. Long-range ($H^{\#}$, $D^{\#}$, or $H_2^{\#\#}$) vs. short-range ($^4He^{\#\#}$) transmutation

(1) Most CF energy may come from direct fusion, but, transmutation (from failed direct-fusion products) may be a major contributor.

(2) Because of angular momentum (centrifugal forces), hydrons may not fuse directly. They can co-rotate in metastable orbits.

(3) Co-rotating hydrons either fuse with each other or with lattice nuclei, as they wander from their source region at thermal velocities.

(4) H+H direct fusion is retarded by the time required to form neutrons (weak interaction).

(5) D+D direct fusion is retarded by the decay time from $D^{\#}$ + $D^{\#}$ or $4He^{\#\#}$ to ^{4}He ground.

(6) $H_2^{\#\#}$, with 2–3 fm electron orbits may be semi-stable (greater than picosecond half-life?)

(7) $D_2^{\#\#}$, with 2–3 fm electron orbits are unstable (neutrons couple, inducing fusion – less than femto-second half-life?)

(8) $H^{\#}$and $D^{\#}$, if formed in failed fusions, are stable and *long-ranged*. Because of much stronger DD bonds and the presence of neutrons, DD-fusion failure (resulting in $D^{\#}$ atoms) is uncommon.

(9) Long-range (microns?) travel of femto-H atoms means mainly lattice atoms are transmuted. However, any radioisotopes (natural or created) in the lattice and any impurities with greater interaction cross-sections are preferentially transmuted.

(10) $H_2^{\#\#}$ and $^4He^{\#\#}$ have short half lives and are thus *short-ranged*.

(11) Short-ranged (nm?) means most transmutations are with lattice atoms and with prior transmutations, where both are near to the source of femto atoms.

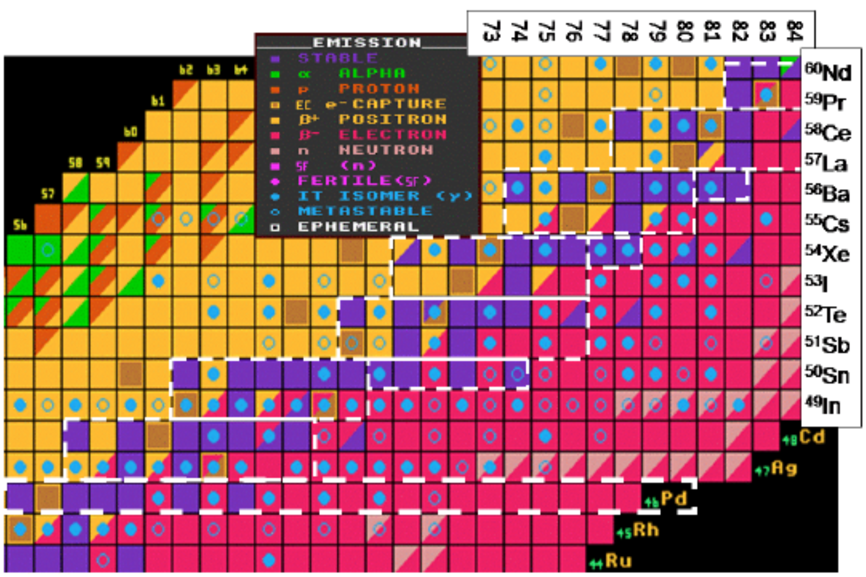

Figure 1. Probable isotopes of transmutations leading from 'neutral alpha' interactions with a Pd lattice and subsequent transmutations (protons on ordinate, neutrons on abscissa).

3.2. Short-range transmutation processes

Long-range transmutation processes, involving $H^{\#}$in the Ni–H system, were described in an earlier paper [7]. The present paper describes the short-range fusion processes in the PdD system. The colored chart below (Fig. 1) identifies the probable transmutation-isotope range of the 'neutral alphas' interaction (dashed boxes) with the Pd lattice and the local buildup of transmuted elements about a nuclear active environment, the NAE. The preferred mode is:

$$^{A}N_{Z} + ^{4}He^{\#\#} \Rightarrow \ ^{A+4}N_{Z+2} \tag{1a}$$

If this mode is not available (i.e., not producing a stable nucleus), then additional options include

$$^{A}N_{Z} + ^{4}He^{\#\#} \Rightarrow \ ^{A+4}N_{Z} + 2\text{ neutrinos}, \tag{1b}$$

$$\Rightarrow \ ^{A+4}N_{Z+1} + 1\text{ neutrino}, \tag{1c}$$

$$\Rightarrow \ ^{A+3}N_{Z+1} + 1\text{p} + 1\text{e}, \tag{1d}$$

$$\Rightarrow \ ^{A+3}N_{Z+2} + 1\text{n}, \tag{1e}$$

$$\Rightarrow \ ^{A+2}N_{Z+2} + 2\text{n}, \tag{1f}$$

$$\Rightarrow \ ^{A+2}N_{Z+1} + 1\text{ p} + 1\text{n} + 1\text{e}, \tag{1g}$$

$$\Rightarrow \ ^{A+2}N_{Z} + 2\text{p} + 2\text{e}, \tag{1h}$$

$$\Rightarrow \ ^{A+1}N_{Z+1} + 2\text{ n} + 1\text{p} + 1\text{e}, \tag{1i}$$

$$\Rightarrow \ ^{A+1}N_{Z} + 1\text{n} + 2\text{p} + 2\text{e}, \tag{1j}$$

$$\Rightarrow \ ^{A}N_{Z-1} + 1\text{ neutrino} + 2\text{n} + 2\text{p} + 1\text{e}, \tag{1k}$$

$$\Rightarrow \ ^{A}N_{Z-2} + 2\text{neutrino } + 2\text{n} + 2\text{p}. \tag{1l}$$

(1m)

The neutrons and protons coming out of the transmutation may be as individuals or as composites (such as alphas). Most of these examples are demonstrated below. Other combinations exist; but, they would depend on having the correct starting isotope, a stable product, and an exothermic reaction. The point is that the DDL electrons allow a multi-nucleon body to enter a nucleus for fusion, fission, or transmutation.

Figure 1 shows the partial range of options available to the neutral alpha ($^{4}He^{\#\#}$) as it encounters different nuclei. There is no intention to provide all of the options, nor to be quantitative about them. This is an initial training exercise, that can be changed dramatically by a single data set (just as the Ni–H model was improved with the Defkalion ^{61}Ni data [11]).

Starting with $^{102}Pd_{46}$ (Fig. 2), the six first order reactions expected (in order of probability) are:

$$^{102}Pd_{46} + ^{4}He^{\#\#} \Rightarrow ^{106}Cd_{48} \quad \text{(no weak interactions)}$$

$$\Rightarrow ^{104}Pd_{46} + 2\text{p} + 2\text{e} \quad \text{(no weak interactions)}$$

$$\Rightarrow ^{105}Pd_{46} + 1\text{neutrino} + 1\text{ p} + 1\text{e} \quad \text{(1weak interaction), 1p} \Rightarrow \text{1n)}$$

$$\Rightarrow ^{103}Rh_{45} + 1\text{p} + 2\text{n} + 1\text{e} + 1\text{neutrino} \quad \text{(1weakinteraction, 1p} \Rightarrow \text{1 n)}$$

$$\Rightarrow ^{106}Pd_{46} + 2\text{neutrinos} \quad \text{(2weak interactions, 2p} \Rightarrow \text{2n)}$$

$$\Rightarrow ^{102}Ru_{44} + \text{alpha} + 2\text{neutrinos} + 2\text{e} \quad \text{(2weak interactions, 2p} \Rightarrow \text{2n)}$$

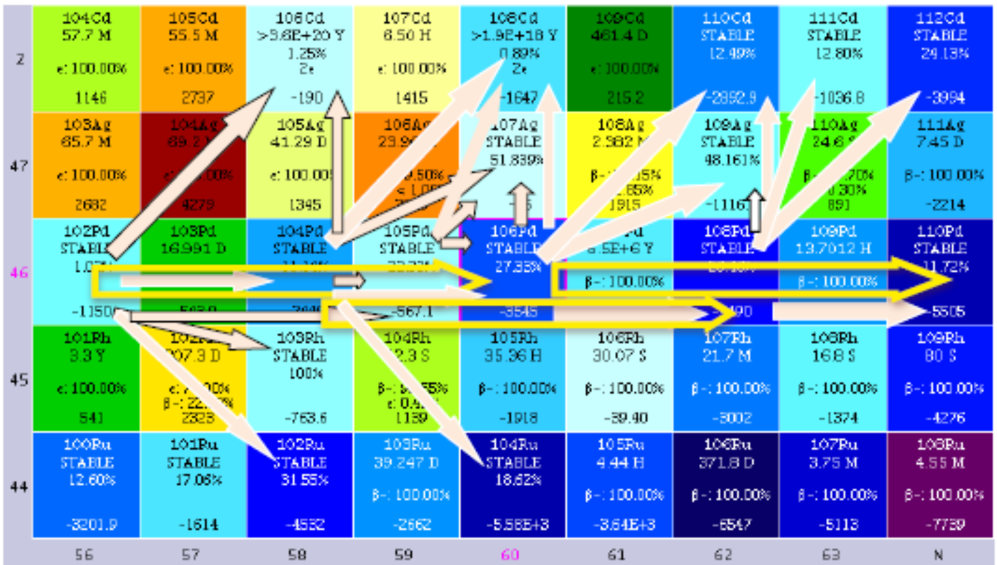

Figure 2. Transmutation of lower mass stable palladium nuclei via femto-helium (neutral alphas). Multiple pathways to stable isotopes are displayed as preferred paths. (Some arrows are outlined only for clarity.)

The normally preferred reaction, $^{102}Pd_{46}+^{4}He^{\#\#} \Rightarrow {}^{106}Cd_{48}$, may be suppressed because that particular Cd isotope would like to get rid of positive charge. However, it is extremely long lived, so it might still provide the strongest transmutation path. The weak interaction probability (p $\Rightarrow$ n by electron capture) is greatly enhanced by the continued proximity of the DDL electron(s) during the interaction of the $^{4}He^{\#\#}$ with the lattice nucleus.

It is clear that a major difference in the present model and conventional views of alpha-induced nuclear reactions has to do with the binding energies of the constituent parts and the presence of the tightly bound electrons. If nuclear collisions occur while the paired deuterons are still high in the common nuclear-potential well, the neutral alpha readily splits into multiple parts that can interact with the target nucleus in many ways. As the deuteron pair decays toward the ^{4}He groundstate, the probability of separating the nucleons is reduced and that of separating the DDL electrons from the nucleus is increased. Thus, the preferred transmutation paths may be dependent on the extent of the $^{4}He^{\#\#}$decay at the time of interaction.

In Fig. 2, transmutation of ^{104}Pd by the $^{4}He^{\#\#}$ reaction has a (nearly) stable target isotope ($^{106}Cd_{48}$) that can be reached by double neutron emission. Even though this cadmium isotope is nearly stable, its preferential decay mode (double positron emission) is so similar to the reverse of the process needed to reach it from ^{104}Pd that the probability of that path relative to the transition to $^{108}Cd_{46}$ would appear to be negligible. The seven 'easy' transmutations to stable isotopes in this interaction are:

The ^{105}Pd isotope has only three options for ready transmutation to stable (or very long-lived) isotopes via neutral alphas. Of these three stable nuclides, perhaps only ^{107}Ag is spin compatible with the neutral alpha transmutation of the ^{105}Pd isotope. (This comment is based on the observed lack of heat generated by the ^{61}Ni isotope in CF reactions [11].) If true, then this observation could lead to a test of the present model.

The ^{106}Pd isotope has a preferred path, from ^{106}Pd to ^{110}Cd, a completely stable isotope (Fig. 3). Therefore, unless something else interferes (e.g. isotopic spin), the present model would predict this path as the main transmutation for

${}^{104}Pd_{46}+{}^{4}He^{\#\#}$	$\Rightarrow$	${}^{108}Cd_{48}$	(no weak interactions)
	$\Rightarrow$	${}^{107}Ag_{47}$ + p + e	(no weak interactions)
	$\Rightarrow$	${}^{106}Pd_{46}$ + 2p + 2e	(no weak interactions)
	$\Rightarrow$	${}^{105}Pd_{46}$ + 2p + 1n + 2e	(no weak interactions)
	$\Rightarrow$	${}^{106}Cd_{48}$ + 2 neutrons	(no weak interactions)
	$\Rightarrow$	${}^{108}Pd_{46}$ + 2 neutrinos	(two weak interactions, 2p $\Rightarrow$ 2n)
	$\Rightarrow$	${}^{104}Ru_{44}$ + alpha + 2 neutrino	(two weak interactions, 2p $\Rightarrow$ 2n)

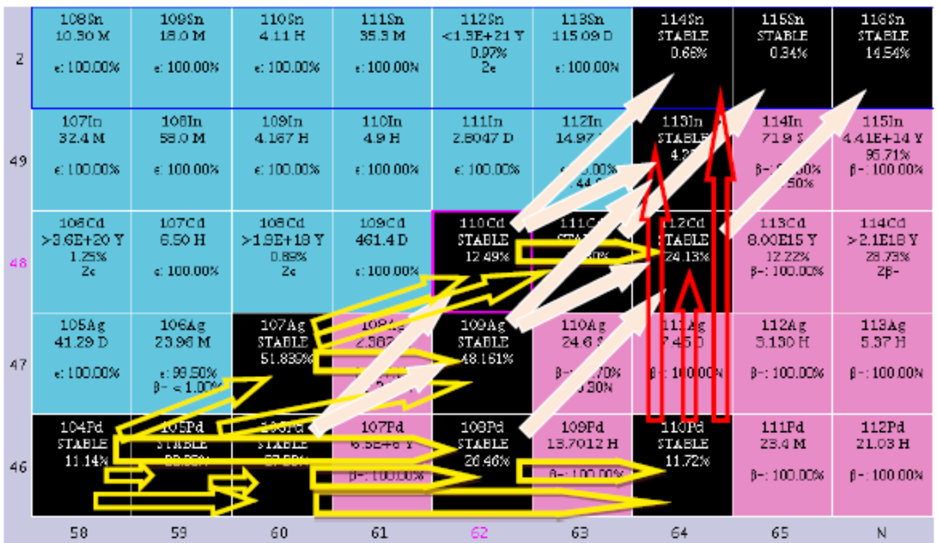

Figure 3. Transmutation of stable nuclei via femto-helium (neutral alphas) toward higher atomic and mass number.

^{106}Pd. On the other hand, if the DDL electrons cannot dissipate the added nuclear energy quickly enough, ejection of one or two protons would also leave the result as a different stable nucleus. This begins the strong growth in transmutations to the higher atomic number nuclides in this family. The probability of the different pathways could be statistical or it could be highly sensitive to various nuclear conditions. CF data from isotopically pure Pd sources could provide a sensitive test for involvement of nuclear physics in this field as such testing of Ni isotopes has been.

The red arrows in Fig. 3 indicate a possible new dominant process (induced-beta decay). In this case: The ejection

${}^{110}Pd_{46}+{}^{4}He^{\#\#}$	$\Rightarrow$	${}^{112}Cd_{48}$ + 2 neutrons	(no weak interaction)
	$\Rightarrow$	${}^{113}In_{49}$ + 1 neutron + 1 neutrino + 1 beta^{-} (electron)	(1 weak interaction, n $\Rightarrow$ p)
	$\Rightarrow$	${}^{114}Sn_{50}$ + 2 neutrinos + 2 betas (electrons)	(2 weak interactions, 2n $\Rightarrow$ 2 p)

of neutrons is not a problem and the induced decay of one or more neutrons is natural. Nevertheless, the possible slowness of the presented weak interactions (despite the DDL electron proximity) could severely retard the latter two reactions.

If an alpha were to be absorbed by the ^{110}Pd, it would go to $^{114}Cd_{48}$, which would double-beta decay to $^{114}Sn_{50}$. The fact that the $^{4}He^{\#\#}$ could induce this action in a single step, because of the presence of DDL electrons, is not a surprise. Similarly, the $^{110}Pd_{46}+^{4}He^{\#\#}$ to the long-lived $^{113}Cd_{48}$ would perhaps lead to a direct transmutation to $^{113}In_{49}$via induced beta decay. According to the model presented here, transmutation to a radioactive isotope via $^{4}He^{\#\#}$ is not an expected interaction, given other options, and thus the unusual direct double-beta decay to $^{114}Sn_{50}$would be a preferred path. If this were a natural pathway for CF-induced transmutation of $^{110}Pd_{46}$, then observation of double-beta decay would be a test for the model and the possibility of observing a neutrino-less double-beta decay [12] would be greatly improved. A potential problem with such a test is the uncertainty in output energies from the multi-body interaction presented. Furthermore, the near-simultaneous de-orbiting of the DDL electrons would provide a source of energetic electrons that would interfere with measurements of double-beta decay coincidence measurements.

The remainder of the predicted neutral-alpha transmutation chain, from Ag thru Xe, follows this same pattern (Fig. 3). Stable isotopes generally lead to stable isotopes, if possible. This is always possible for neutral alphas in this range. Sometimes unstable isotopes can result, but they are unlikely to decay before they are transmuted again into a stable isotope.

Since alpha bombardment of most of these isotopes yields only a few MeV per nucleon, it is clear that the major excess energy in CF in the DD system is from the formation of ^{4}He and not from any transmutations. The increase in 'energy added per nucleon' for lower atomic number nuclides indicates a need for considering further the contribution of fission in the analysis [8].

4. Selective Fusion

At ICCF-17, in an attempt to account for the negligible rates of energetic radiation from neutron-activated transmutations that would normally produce high levels, two mechanisms were invoked. Both involve the presence of DDL electrons, but at different stages of the initial fusion process. The presence of DDL electrons has been used to describe the initial-decay process of ^{4}He* in D–D fusion [4]. Since the transfusion process described here involves Femto-atoms and molecules, such DDL electrons must also be incorporated into (or about) the transmuted nucleus during/after fusion with a femto-atom or molecule. With such incorporation, these deep-orbit electrons would provide a much more rapid decay path, via near-field coupling of the nuclear energy to the DDL electron(s) and then from the DDL electrons to the lattice atomic electrons [4]. This accounts for the reduction or elimination of radiation from fusion products that are highly radioactive, if produced by only the addition of neutrons.

The second mechanism is a bit less obvious; but, if valid, of major importance to CF and the observed results. Mentioned in the ICCF-17 posters, but not described in detail in the published version [7], is the selective-attraction of the femto-atoms to radioactive nuclei. In [4], I use Maxwell's equations to indicate the relative E-field strengths generated by nuclear protons, DDL electrons, atomic electrons, and radio-nuclides. The fact that radio-nuclides have energetic protons that 'want' to give away energy and the DDL electrons of femto-atoms can receive it (at nuclear frequencies) means that work can be done. This provides an attractive potential between the two.

Using Feynman's description of the H-molecular ion, the Yukawa exchange potential, and his extension to the photon as the mediator of the Coulomb potential, one may provide a mathematical and conceptual basis, for sufficient attraction between femto-hydrogen atoms to fuse or to form femto-molecules. (The draft of that paper is already 10 pages long.) Formation of the femto-hydrogen atoms and molecules, because of their ability to liberate 6–8 MeV per incident nucleon in fusion leading to transmutation, could be an important contributor to excess-heat generation in the Ni–H and Pd–H systems. These two systems have their own transmutation profiles that partially overlap with that of the femto-helium system described here and that of the femto-hydrogen described earlier. Femto-deuterium molecules may be unstable, rapidly decaying to short-lived $^{4}He^{\#\#}$, so that only transmutation via the $^{4}He^{\#\#}$ atoms is considered here.

5. Consequences

Long-range transmutation in the NiH system via femto-hydrogen atoms or molecules is a meaningful contributor to the excess heat observed. It may actually dominate the contributions from direct p–e–p or p–e–e–p fusion reactions in that regard. The transmutation results are spread over a large area around a source region and primarily shifts the isotopic distribution of nickel in the lattice rather than producing new elements. This may be important if the source of the excess-energy production and femto-atoms (e.g., a nuclear-active environment – or NAE) is dependent on the integrity of a nickel structure.

It is unlikely that the isotopic nature of the nickel would alter the production of direct p–e–p or p–e–e-p fusion reactions or femto-nuclei. Nevertheless, the negative results for ^{61}Ni may belie that statement [11]. These results, which may be explained in terms of isotopic-selection rules, could point to which is the major source of excess energy. Since ^{61}Ni is only a small percentage of the isotopes in the natural material, this unexpected result has little impact on the heat producing capability of the Ni–H system. Even as the levels of the isotope build up, if it does not interfere with the production of the femto-hydrogen, then the long-range of these femto-structures would find a nearly infinite supply of productive Ni isotopes.

In the Pd–H system, the femto-hydrogen created could transmute Pd to silver (Ag) in the source region. Even if long ranged, this addition of Ag to the Pd lattice could 'poison' the CF action (or it could help it by raising the Fermi level in the local lattice). However, if the source of femto-hydrogen is local, the concentration of transmutation products would be highest in the source region. Creating an alloy in the NAE of a PdD system could be a severe, life-limiting problem for CF activity.

Short-range transmutation in the PdD system is another story. Because the production of ^{4}He generates a majority of the excess heat in this D–D fusion system, creation of 'neutral alphas' is not critical to the system's heat-production function. However, their creation presents a problem. Being short range, they will alter not just the isotopic distribution in the source region; they will quickly alter the elemental composition of the source region itself.

Assuming that the new elements created interfere with the activity within the NAE, this effect would appear to be a severe limitation to CF in the PdD system. The NAE sites would rapidly destroy themselves with their own by-product. The only redeeming feature is that the neutral alphas are short ranged because they are short lived. Thus, while high concentrations of new elements may accumulate about an NAE (until it ceases to function), the actual rate of transmutation may be low.

How does the short-range transmutation affect the Ni–H system? As with the Ni–H system, where most of the transmutations are to other Ni isotopes, the Ni–D system would behave in the same manner. The path out of the Ni isotopes would be primarily via ^{64}Zn and ^{66}Zn, although ^{63}Cu and ^{65}Cu might be available as well. The consequences of these elements in the NAE region are still to be determined.

In the Ni–H system, isotopic selection rules appear to retard production of the Cu isotopes. This might, or might not, be the case for the Ni–D system. If nothing retards the formation of the heavier elements from the fusion with the short-range neutral alphas, then the Ni NAEs might lose their effectiveness faster in the Ni–D system, than in the Ni–H system. These effects may also apply to the PdH and PdD systems. How they affect the transmutation of lattice and impurity nuclides is still to be determined. The present model fits the available CF data and appears to be highly predictive. Time will tell.

6. Conclusions

The present model indicates that transmutation occurs in varying amounts and distributions in tested Cold Fusion Systems (Pd–H, Pd–D, Hi–H, and Ni–D). I believe that the deep-Dirac level electron is the only mechanism that can overcome the Coulomb barrier of lattice nuclei without invoking neutrons that would produce results incompatible with well-known neutron-activation products. The common belief that neutrons are the only low-energy mechanism that can produce transmutation has blocked acceptance of both CF results and models for many years.

The existence of DDL electrons, proposed to account for the ability to produce ^{4}He as the primary product of D–D fusion, also explains the available CF transmutation data. This paper, explaining the direct-transmutation products of the Pd–D system, via the neutral femto-atom concept, complements the prior work on the Ni–H system. It is not the whole story, which must include both transmutation of the Pd lattice nuclides and any contaminants or dopants included. It also must include the fission of these nuclides and their fusion products. These parts of the story must await a future effort.

The proposed model suggests transmutation from both short-range femto-deuterium molecules and long-range femto-hydrogen atoms and molecules. The former is likely to alter (by saturating a region with multiply-transmuted atoms), and ultimately inactivate, its source regions (assuming the validity of a concept of nuclear-active environment sites). The latter, by widely distributing the transmuting species, has much less effect on the sources of femto-hydrogen. In fact, the majority of transmutations would be to higher mass Ni or Pd isotopes and thus have no effect on the CF process.

A final mechanism, selective attraction of femto-atoms to radio-nuclides (that affects the short-range and long-range transmutations differently) is addressed. This effect reduces (possibly eliminates) residual radioactivity from the transmutation process or from radioactivity introduced into the lattice. The effect further concentrates transmutations about the ^{4}He$^{\#\#}$ sources and to a lesser extent about the femto-hydrogen sources.

The careful work by Mizuno [8] indicated that transmutation and subsequent fission may play a major role in the excess energy from cold fusion in PdD lattices. The processes leading to the many transmutations in PdD described here could also lead to fission in the same manner as would neutrons.

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