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Research Article

Implications of the Electron Deep Orbits for Cold Fusion and Physics – Deep-orbit-electron Models in LENR: Present and Future

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Abstract

Relativistic deep-orbit electrons (D-O-Es) have previously been identified as the probable mechanism in the development of low-energy nuclear reaction (LENR) theories based on experimental Cold Fusion (CF) results. This present paper highlights how relativity and the near-field interactions (of deep-orbit electrons with both the nucleus and the lattice) predict accepted and many reported, but not-yet-accepted, CF observations. Included in the former category are: all of the new fragmentation ratios for the D+D $\Rightarrow$ ^{4}He CF nuclear reaction; a high-probability p–e–p $\Rightarrow$ d reaction; a 'fast' decay process for transitions from excited to ground nuclear states; and a means of transferring excess nuclear energy to the lattice. Included in the latter category are: energy transfer from s-orbit atomic electrons to low-lying nuclear states; the formation of femto-atoms and femto-molecules – a basis for transmutations without the known 'hard' radiation (particulate or photonic) characteristic of neutron activation processes; selective attraction of femto-atoms/molecules to radio-nuclides (nuclear remediation); and the 'preferred' transmutation pathways in CF. Other effects, based on the published deep-orbit models, are predicted. Because of the successes of these models in explaining so much of CF, their mathematical basis is presently being explored beyond previous work(s). The physical bases for, and the consequences of, the mathematical predictions are proposed and described here. These include: special relativity and binding energy; the deBroglie term and spin-axis precessions; the deep-orbit quantum number, k; and deep-level splitting from spin–orbit, spin–spin, momentum and magnetic interactions. Theoretical concepts such as: symmetry breaking, 'sequestration', and elementary-particle mass changes to below their rest mass are also addressed. The new results and their interpretation, while incomplete, provide both satisfaction (in resolving prior issues) and surprises (in the magnitude and variety of near-nuclear effects).
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Keywords: Femto-atoms, 500 keV binding energies, Near-field interactions, Nuclear remediation, Relativistic bound electrons, Sub-restmass nucleons, Transmutation

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1. Introduction

For over two decades, relativistic deep-orbit electrons (D-O-Es) have been identified as the probable mechanism for the development of low-energy nuclear reaction (LENR) theories based on experimental Cold Fusion (CF) results. The initial work of Maly and Va'vra [1] in applying this decades-old concept to cold fusion was 'debunked' by Rice, Kim, and Rabinowitz in an exchange of letters to the editor [2] and of papers [3] that performed a critical analysis of all of the CF models of the day. Their criticism was not based on the decades-old mathematical arguments against deep orbits themselves, but on physical principles and concepts: "In this letter, we show that these solutions are unphysical, and thus, these deeply bound energy levels cannot exist." The RKR criticism did include some math differences with the M&V work; however, these were on a different level than earlier criticism of these orbits denying the validity of the anomalous (deep-orbit) solutions of the Klein-Gordon and Dirac equations. Our interpretation of the RKR derivation for the anomalous solution does not deny the existence of the deep orbits (even though RKR claim that it does), but those authors discount their importance. Nevertheless, in their dismissal, they still provide some invaluable information: the contribution from the 'deep-orbit' portion is only two parts per billion. This interpretation is quite different from the 'blind' adherence to the 'pure' mathematics for a $1/r$ Coulomb potential that denies the acceptability of the anomalous solution. *It allows for a cold fusion process to raise that contribution to a 'useful' level.* However, it is doubtful that RKR would share this interpretation.

The RKR letter concludes with two physical bases for rejection: "If such orbits existed, upon collision, they would produce fusion at a much higher rate than muon-catalyzed fusion. So, their (M&V) proposed solution does not get around the nuclear ash problem." The first statement is absolutely correct. It accounts for the non-observability of a deep-orbit electron population. The second statement is false. It is precisely because the deep-orbit electron solves the nuclear ash problem that this concept is so important to CF and why this present paper addresses this and other implications of the deep orbits to CF.

This present paper highlights how relativity and the near-field interactions (of deep-orbit electrons with the nucleus and the lattice) predict accepted and many reported, but not-yet-accepted, CF observations. Included in the former category are: all of the new fragmentation ratios for the D+D $\Rightarrow$ ^{4}He CF nuclear reaction, a high-probability p–e–p $\Rightarrow$ d reaction, a 'fast' decay process for transitions from excited to ground nuclear states, and a means of transferring excess nuclear energy to the lattice. Included in the latter category are: energy transfer from s-orbit atomic electrons to low-lying nuclear states, the formation of femto-atoms and femto-molecules – a basis for transmutations without the known 'hard' radiation (particulate or photonic) characteristic of neutron activation processes –, selective attraction of femto-atoms/molecules to radio-nuclides (nuclear remediation), and the 'preferred' transmutation pathways in CF.

2. Theoretical Concepts

Several theoretical concepts contributing to deep orbit models are described below:

(1) symmetry breaking (phase change),
(2) proximity effects,
(3) 'sequestration' (isolation of effects, [4]),
(4) elementary-particle mass changes to below its rest mass (energy conservation),
(5) Relativistic enhancement of the Coulomb potential (dynamic vs. static).

None of these concepts are esoteric, but neither are they commonly used.

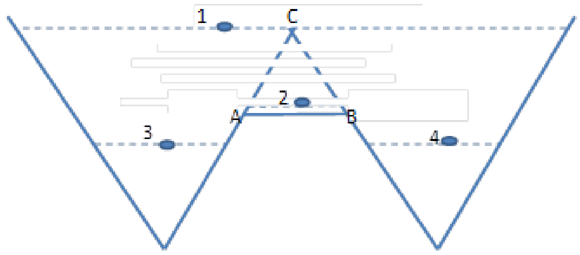

Figure 1. Schematic of a potential with energy-level-dependent symmetry.

2.1. Symmetry breaking (phase change)

Symmetry breaking is a phenomenon in which small (perhaps infinitesimal) variations of a system at a critical point may decide the system's fate, by determining which branch of a bifurcation is taken. Change in energy level may be such a variation. Figure 1 gives an example of symmetry breaking that applies to the cold fusion phenomenon. Objects at levels 1 and 2 have the same symmetry about the central axis. Moving, from 1 or 2 to 3 or 4, obviously changes symmetry. Nevertheless, moving from region 1 to region 2, while not a change in axial symmetry, still requires a change in energy (slight) and in dimensionality (large) at the critical point (C). On the other hand, if the dotted lines represent discrete states, a change from 1 to 2 requires a not-so-slight change in energy and a much smaller change in dimensionality.

Classically the change from state 1 to state 2 is a continuous process. This gradual change is seen as a phase change. However, change can be gradual or abrupt; both are the same, it is only a matter of degree. Quantum mechanically, the transition from state 1 to state 2 is a quantum jump. However, QM allows a 'mixing' of states 1 and 2 that still represents a phase change through the region between.

Changing Fig.1 to represent a cylindrical potential well in 3-dimensions introduces additional concepts of the critical points. In such a 3-D picture, regions 3 and 4 are joined; but, depending on the nature of the barrier, an electron in the joined region will not generally cross region 2. Electrons orbiting in this joined region will bounce back and forth between the potential walls as they move around the annular region. There are now two additional critical points that have no particular spatial location. At one of them, in angular momentum space, the electron could bounce back and forth between the potential walls, but not move around the annular region. The other, at a specific radius, will have the electron in a circular orbit that never touches the walls.

The 3-D version of Fig. 1 schematically represents the atom; however, the inner repulsive core is now from centrifugal force leading to a pseudo potential with different properties. The state 1 represents the atomic orbitals with the nuclear region as a central point. The state 3+4 represents the deep orbitals where an electron 'sees' the nuclear region as being the whole horizon. The relativistic Coulomb potential (mentioned below) has a repulsive core. In the state 1, the angular momentum would have to be almost zero ($l = 0$) for the electron to pass near to the nucleus. As an example, the s-orbital electrons are the only ones that strongly interact with the nucleus in internal conversion where nuclear energy is transferred directly to an atomic-orbital electron.

In the state 3+4, the deep-orbit electrons cannot have stable orbitals with zero angular momentum, $l = 0$. Such a condition is a critical point and any perturbation would give it rotation and $|l| > 0$. Can it have zero angular momentum within the Heisenberg uncertainty relation (HUR is $\Delta x \cdot \Delta p \geq \hbar$) where Δx is within the multi-fermi range? Again, the answer is no. The energy required to obtain the needed momentum would not allow the electron to be bound. (This is an argument often used against the concept of deep-orbit electrons. It is addressed further below. However, the relativistic enhancement of these electrons versus the repulsive core is still to be fully explored.)

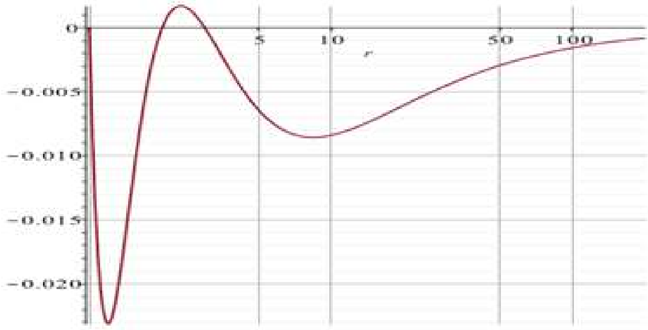

Figure 2. Plot of Eq. (1) with values of constants to represent standard and relativistic (proximity) effects.

Change in effective mass is generally considered to be a change in symmetry (e.g., pair production from a photon is 'two fermions from a boson'). Mass is associated with charge (a static electromagnetic, EM, energy). In pair annihilation, both mass and charge change phase to become a photon, an oscillating EM field. Thus, mass change is really a phase change from mass energy to EM energy. We believe that an understanding of this mass change is critical to the acceptance of DD $\to^4$He cold fusion.

2.2. Proximity effects

Symmetry change is associated with proximity to critical points. Various interactions have different radial dependencies. The full expression for potential of an electron about a nucleus is of a type:

$$V(r) = C_1/r + C_2/r^2 + C_3/r^3 + C_3/r^4, \tag{1}$$

$$V(r) = C_b.\text{pot.} + \text{centrifugal} + \text{spin–orbit} + \text{from } A^2 \; (A : \text{vector potential}).$$

The first two terms on the right-hand side define the atomic orbitals where the angular momentum L in the centrifugal term, $L^2/2mr^2$, balances the attractive Coulomb potential to produce the minimum in the right-hand side of Fig. 2. As r gets small, proximity effects dominate and the third and fourth terms compete to create a minimum in the left side of the figure, in which the semi-log plot expands the low-r region.

If scaled to the atom, the two minima shown, one provided by the first two terms of Eq. (1) and one by the relativistic effects of the last two terms, are a factor of ∼20 apart in the figure. Actual relativistic effects provide the second minimum to be ∼4 orders of magnitude below the radius of the first (∼5 fm vs. ∼50 pm) and more than four orders of magnitude deeper (∼500 keV vs. ∼10 eV). Thus, the deep-orbit minimum is much more isolated than shown in the figure.

2.3. 'Sequestration' (isolation)

The opposite of proximity effects is sequestration. The strong relativistic effects of the deep-orbit interactions, because of sequestration, have negligible effect on low-Z atomic systems. However, they could dominate in the near-nuclear regime. Sequestration does not have to be from spatial isolation. Some sequestration is perceptual or geometric. To an

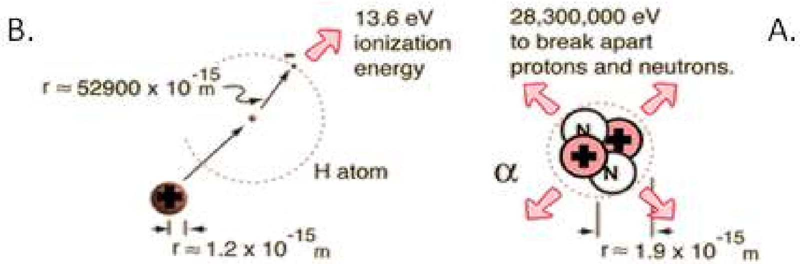

Figure 3. Comparison of atomic and nuclear scales and binding energies.

atomic electron, the nucleus is a 'speck' in the distance. To a deep-orbit electron, the nucleus is the constant horizon. The former is sequestered from the nuclear forces.

Relativity might be considered to have a major impact at both ends of the velocity scale. An electron in motion has a magnetic field **B**; a stationary one does not. Any velocity will create both the **B**-field and kinetic energy; however, the energy of the **B**-field is also an incremental increase in electron mass. Velocity removes the sequestration and the input energy goes into both mass (EM) and kinetic energy. Nevertheless, the mass increase is not observable until velocity is near 'c' because the electron has a starting mass that masks the effect at low velocities.

Some sequestration is not from the spatial isolation (e.g., a $1/f(r)$ dependence); it is isolation from the consequences of proximity. An electron in an s-orbit is more massive when closer to a nucleus (where it is moving faster) because of relativity and the increased bound electro-magnetic fields. An important question for CF is "where does this mass energy come from?"

2.4. Mass change to below rest mass (energy conservation)

It is obvious that, when a stationary charge is moved, a portion of the energy creating the motion goes into kinetic energy (KE), as easily measured velocity, and a portion of the energy goes into distortion of the static electric field, **E**. This distortion is the easily measured magnetic field (**B**). Inertia is the resistance to change in velocity, **v**, and acceleration, **a**, is a measure of that change ($\mathbf{a} = \mathrm{d}\mathbf{v}/\mathrm{d}t$). Since $\mathbf{a} = \mathbf{F}/m$, one can see that mass and inertia are closely related. We could extend the concept of mass to that of 'effective mass' to make the relationship complete. In doing so, and in examining the consequences, we are able to get to a better understanding of mass. Some illustrative examples are helpful in this pursuit.

The mass of a nucleus is always less than the sum of the individual masses of constituent protons and neutrons. The difference is a measure of the nuclear binding energy. Nuclear binding energy, $\mathrm{BE_N} = \Delta mc^2$ is generally many MeV. Figure 3 indicates the energy required to ionize a hydrogen atom and to separate all of the nucleons of an alpha particle. The energy difference ($\Delta E = \Delta Mc^2$) in the process of forming a nucleus is often given off as gamma rays (γ); so we see mass being directly converted into EM radiation. Proton and neutron masses in a nucleus are less than their respective rest masses. The ΔM is from symmetry breaking and loss of sequestration as two nucleons or nuclei come together and, in a proximity effect, their potentials (nuclear and EM) interact.

Similarly, in the hydrogen atom, H, photo decay of an electron from an excited state results in a loss of mass and this is equivalent to the atomic-electron binding energy, $\mathrm{BE_A}$, or its ionization energy (Fig. 3B). Since the electron moves faster in the lower state, it gains mass in getting there. The emitted photon energy must come from the proton's mass (see Appendix). A phase change begins in the proton and electron as (spatial) sequestration is lost. We have seen that distortion of the static electric fields (of a stationary charge) stores energy expressed in the form of magnetic fields. The interaction of the electron and proton fields is the source of an increase in electron kinetic and mass energy.

The increase in the combined field strength and energy between the electron and proton also is stored energy. Since the electron is orbiting about the proton, the phase change includes not just a distortion of the fields (of stationary to linear velocity), it includes the change from an electro-static to an oscillating-dipole field (of linear to bound motion). In the case of the electron, which is considered to be 100% EM energy, it is expected that the change in fields is both external and internal. The proton, nearly 100% EM energy [4], is also expected to have changes in both external and internal fields. The fields of the relativistic charged quarks inside the proton must respond to the proximate electron's field just as the electron responds to their combined charge field. The result of polarization of the quark charges (another proximity effect) is stored energy. However, the net effect of the presence of the electron field is to lower the bond energy between the quarks (and perhaps between their constituent parts). Thus, the energy (mass) of the proton(s) is reduced enough to provide for the strengthened fields between the proton and electron and the emitted-photon energy.

There is no question of the loss in mass of nucleons as a result of neutron activation. There is probably no reason to ask if some of the nucleons change more than others. There is no question of the loss in mass of atoms resulting from photo-decay. The percent loss in mass of the nucleons is too small to be detected, so there is probably no reason to question if some of the nucleons change more than others. If the electron mass were reduced by the binding energy, spectrographic analysis is sensitive enough to detect a 10 eV change in a 511 keV mass electron. Has this ever been sought?

The decay process to a deep-electron orbit is energetically between that of atomic-electron photo-decay and that of nuclear fusion. However, no experiments have yet shown incontrovertible evidence of either the high-energy ($\sim$1/2 MeV) photo emission from electron decay to the deep orbits or from electron capture preceding an atomic electron fusing with a proton to form a neutron. Nevertheless, if the relativistic effects of a proximity interaction of the Coulomb potential in the nuclear region, or of some other process to absorb the excess potential energy resulting from the change to deep-electron energy levels, is present, then the predicted BE of $\sim$500 keV, plus $\sim$1 MeV (from kinetic energy) per electron would be subtracted from the nuclear mass.

2.5. Relativistic effects at small *r*

When an electron gets close to a nucleus and relativistic effects become important, a number of things are different. The virial theorem, which provides the relationship between kinetic and potential energies for stable orbits in a central potential, gives different values for relativistic particles. For a $1/r$ (Coulomb) potential, the non-relativistic relation is KE $= -$PE/2. This non-relativistic relation is the reason that atomic electrons decaying to lower levels require photon emission. Energy (e.g., photonic, E_{ph}) needs to be released so that the change in potential energy of the two orbits is matched by the change in kinetic and photonic energies, Δ|PE|$=\Delta$KE $+\Delta\mathrm{E}_{\mathrm{ph}}$. As the velocity approaches the speed of light, KE approaches |PE|. Thus, decay within relativistic orbits requires a much smaller percentage of the transition energy to be dissipated by photon or some other mechanism.

For non-relativistic stable orbits in a $1/r^2$ potential (e.g., in Eq. (1)), the non-relativistic virial theorem states that ΔPE $= -\Delta$KE. As the velocity approaches the speed of light, KE approaches 2|PE|. This means that, for relativistic orbits in a $1/r^2$ potential, it takes extra energy to 'decay' to a lower orbit. This effect continues for higher order potentials. Remembering Eq. (1), we see central potential components up to $1/r^4$. These effects are seen in Fig. 1. One of the consequences is that the requirement for removal of energy from a system (e.g., by photo emission) to allow decay to lower orbits may no longer be valid in the near-field regime. The potential barrier between the two 'wells' may be only a few fermi thick. This means that tunneling between the two would be nearly 100%. However, there remain other barriers.

The first barrier is the angular momentum problem. To even encounter a deep well, an electron must have near-zero angular momentum. This is not the $l = 0$ of the atomic orbitals which allows $l \leq \pm\hbar/2$ for that state. If the outer radius of the deep orbit is $>10^4$ smaller than that of the atomic orbital, then the cross section (just for encounter) is

$>10^8$ smaller. This is close to the RKR-predicted population of the deep orbitals of 2 ppB of the atomic ground state.

The second barrier is that of energy levels within the deep well. The Heisenberg uncertainty relation says that levels can exist in the nuclear region only for electrons with kinetic energies $\sim$100 MeV. Low-energy electrons trapped in atomic orbits will only see the deep levels as a small perturbation in the potential well of their shallow levels. An understanding of what determines an energy level is required to address this issue. This is an issue for another paper.

A third barrier, related to the first two, is one of probability and mechanisms. Assuming that a stable energy level exists within the deep well, what is its nature in terms of energy and angular momentum? These properties must be matched in some way to those of the electrons that could possibly populate them. Not only must the s-orbital atomic electrons that occasionally hit the small near-nucleus-sized target, they must have the correct 'approach' or the encounter would only be that of scattering from a resonant state.

Do we correctly interpret the relativistic quantum mechanics to predict the existence (and nature) of stable orbits in the deep levels? Do the Klein–Gordon and Dirac equations (properly) incorporate *all* of the relativistic effects? Presently, based on the calculated total energy, TE, for an electron of a few keV, both models predict deep-orbits with binding energies, BE, at the 500 keV level. For relativistic electrons, where the values of KE approach that of |PE|, both may be much larger than the static Coulomb potential would predict [5]. Even if both KE and |PE| are in the 100 MeV range, the binding energy could still be as predicted at $\sim$500 keV. This uncertainty in energies is the greatest unknown at the present time.

A few causes of these uncertainties that are presently being considered include:

- Spin–orbit (SO), spin–spin (SS), and magnetic (**B**) effects could greatly increase both the electron kinetic and potential energies, while the binding energy, BE, can remain the same.
- Relativistic and tight-orbit effects still need to be determined for SO, SS, and magnetic-field functions. Anisotropic enhanced forces (γ vs. γ^3, for acceleration perpendicular vs. parallel to velocity vector) result in circularization of deep-electron orbits
- Effects of velocity dependence of mass. Bound (non-emitted) EM field increases electron mass, which increases centrifugal force

3. Cold Fusion Observations Explained

Perhaps as a most fortuitous circumstance, the origin of cold fusion was based on the PdD system. It presented a seemingly insurmountable intellectual barrier in that the deuterium–deuterium fusion process was so well known – and known to differ greatly from the proposed CF results. The expected fragmentation products (p, n, t, and ^{3}He) of the known D–D reaction were observed at levels orders of magnitude below those commensurate with the excess heat measured. Only later, when the presence of excess ^{4}He in CF was incontestable and highly correlated with excess heat [6], could the challenge that "the low-temperature D–D fusion reaction was not a source of excess heat" be met with certainty. The problem of overcoming this well-known reaction with a new physics process required a method of surmounting the Coulomb barrier between two deuterons as well as a model for preventing the known fragmentation of the fusion product [7]. Had CF originated in a hydrogen system (H+H $\Rightarrow$ D + neutrino), the Coulomb barrier would have been the only perceived challenge and many of the other observations of CF and its true nature could not have been modeled.

3.1. D+D fragmentation ratios

It has long been 'known', within the CF community, that one (or more) electrons are required to spend a greater than 'normal' time between the nuclei to overcome their Coulomb barrier. Almost no models have been proposed to address the fragmentation issue. To date, only two models are able to explain both the Coulomb barrier penetration and the avoidance of fragmentation in the D–D fusion process [8,9]. Both models utilize lattice confinement to increase the depth of the atomic/molecular potential wells and electron levels. The extended lochon model [10] has electron pairs temporarily bound to one of a pair of deuterons by the lattice **E**-fields oscillating in response to phonon resonance. The linear-H molecule model [11] and Storms' crevice model [12] propose linear and planar-to-linear confinement respectively to increase the electron density between nuclei in a linear, many-atom, H-molecule that is only loosely bound to the confining lattice. The longitudinal-optical phonon modes of the linear molecule (a sub-lattice) have much greater oscillation amplitudes because of their loose binding to the lattice and the enhanced screening from their more-centralized electrons. This, in turn, deepens the potential well about and between the nuclei to further confine the electrons and initiate the fusion process. The two models differ beyond this point as to the details of the fusion process.

The extended-lochon and linear-H (or -D) models propose that the transition of one electron from atomic to deep orbits lowers the proton masses sufficiently to eliminate the neutron+^{3}He fragmentation mode [10], A bound pair of deep-orbit electrons will lower the proton masses sufficiently to also eliminate the proton+tritium fragmentation mode [10]. The proximity of the negative electron(s) to the nucleus also reduces repulsion between the proton pair and this, when added to the reduced-mass effect, raises the proton + ^{3}H fragmentation level above the input-energy level. Thus the CF D–D fusion reaction takes place beneath both fragmentation levels and perhaps even beneath the nuclear levels that would permit photo-decay. Even if fusion takes place above these levels, near-field (proximity) electro-magnetic coupling of the relativistic D-O-Es, tightly-bound to both the nucleus and the lattice [13], may still provide the fastest decay mode for removing the excess nuclear energy.

The crevice model proposes (in my interpretation, based on the linear-H model) that the oscillating hydrogen or deuterium atoms in a sub-lattice periodically come close enough together for the excess energy of the fusing nuclei to express itself, but not close enough to initiate fusion. The model's periodic, pulsed, attraction of the adjacent nuclear potential wells and the nuclear Coulomb fields for the bound electrons adds to the atoms' oscillations and this added energy is emitted as photons to be absorbed by the lattice. The nuclear energy of fusion is thus transferred to the many-atom H-molecule before fusion actually takes place.

Aspects of the crevice model have not been accepted because they appear to badly violate accepted physics. The possibility of gradually transferring nuclear energy to the lattice is one apparent violation and the variable lattice spacing of a collapsing multi-H molecule is another. Nevertheless, in 1991 Nobel Laureate Julian Schwinger provided just such a model for nuclear energy transfer [14] (however, he used phonons rather than photons as the transfer medium) and, in 1999, K.P. Sinha provided the quantum mechanical basis for fusion, if the lattice spacing can be varied [15]. Unfortunately, neither of these supporting concepts has been well-received either.

While the presence of screening electrons in some form is generally accepted within the CMNS community as a means of overcoming the Coulomb barrier between nuclei, it is not universally accepted as the only means of doing so. A deep-orbit electron about a proton forms a neutral femto-hydrogen atom H# with a diameter that is not much greater than that of a neutron. The deep orbit automatically brings an electron into the full screening regime so that fusion of a femto-H with another nucleus is quick and nearly inevitable. For this reason, it can be considered as a 'fat' neutron and is a strong transmutant. The p–e–p reaction is known in the solar nucleosynthesis story. Being a 3-body interaction, it is even slower than that of the p–p reaction. However, a femto-H interacting with a proton is essentially a 2-body interaction that gives a very-high-probability p–e–p $\Rightarrow$ H# + p $\Rightarrow$ d reaction to explain the light-hydrogen cold-fusion reactions.

3.2. A 'faster' nuclear decay process

A decay process for transitions from excited-nuclear to ground states, which is faster than normal gamma-emission processes, would explain many observed CF results. If it were faster than fragmentation processes, it would even explain some of the more unusual CF results. Are such processes possible and, if so, are they available? A very few such process models have been proposed. However, since this is not a review paper and must be limited in length, we will only mention (and reference) how the deep-orbit electrons perform this task.

Gamma decay is a photo-emission process. As such, it is normally associated with a doubly resonant energy and momentum transfer [16] between fixed nuclear-energy levels, with specific angular momentum difference ($\Delta l = 1$), and a transfer medium, the bound electromagnetic (EM) field. At some point, this field energy is also resonant with, and becomes, a free photon, which subsequently may be absorbed in scattering or in another resonant transfer with atomic electrons. The nuclear-energy transfer to a D-O-E is non-resonant [17] because the electron can absorb EM energy from the charged nucleon(s) and transfer that energy to the lattice without ever forming a stable new orbit or a photon. Since an excited nucleon can lose energy to an atomic electron transiting the nuclear region without changing its angular momentum (as in the proximity coupling of internal conversion), it can more readily lose it to a D-O-E, which always is close to the nucleus. Furthermore, since the nucleon and deep-orbit electron natural frequencies are orders of magnitude closer together than are the nucleon to atomic-electron frequencies, it is also possible for the nuclear energy loss not to be quantized. This is a direct EM transfer without a photon's requirement for change in angular momentum [18]. In the case of D+D $\Rightarrow$ ^{4}He, both the excited nucleus and the D-O-E(s) have $l = 0$, so $\Delta l = 0$. Thus, no photon is involved. The known reaction of this form is that of internal conversion (IC), which is the preferred decay mode between states of equal angular momenta.

Photo-emission, when not forbidden, is faster than the internal conversion of atomic electrons. However, because of the constant proximity of the D-O-E to the nucleus and their comparable frequencies, the IC rate of D-O-Es may be more than twenty orders-of-magnitude faster than that of atomic electrons. Another critical factor for the high decay rate of an excited nucleus via IC, which has not been previously mentioned, is the high binding energy, BE, of a D-O-E. The BE of s-orbital atomic electrons is 10 eV <BE $<$ multi-keV, whereas that of a D-O-E is $>$500 keV. This means that the atomic-electron ejection of normal IC becomes only an excitation (perhaps a large one) of a D-O-E. Thus, the excited deep-orbit electron will remain bound, deliver its excitation energy to the lattice (by various means [13]) and be able to repeatedly absorb more energy from the nucleus. This extension of a well-known concept (IC) to a different orbit explains how the D-O-Es may provide a nuclear-decay path that could be fast enough to reduce, or even eliminate, fragmentation as well as photo-decay in ^{4}He or other transmutations involving D-O-Es, even if the nucleon masses were not reduced by their presence. Actual values of relative decay rates still need to be determined.

4. Not-yet Fully Accepted Cold-Fusion Observations Explained

After the ICCF-14 conference in 2008, thinking of how DD fusion could lead to ^{4}He without fragmentation led to thinking of classical deep transits of perturbed s-orbital electrons [19,20]. Finding that relativistic quantum equations predicted actual deep orbits was a revelation that opened the door to a new theoretical model of cold fusion with far-reaching consequences [10]. Some of these consequences, such as transmutation without any characteristic radiative decay, had been and were being announced in the experimental-CF literature at that time. However, since there was no theoretical basis for such results, which differed so greatly from known neutron-activation data, many of those who had accepted the original CF premise did not credit the new information.

One of the present authors (AM), who was working on theoretical means of overcoming the Coulomb barrier at the time of a workshop on transmutation [21] at ICCF-14, considered the transmutation data to be interesting (if true) but did not feel it would be useful in determining the 'real' processes of CF. However, as the deep-orbit electron model was being developed [10] and matured [17] and transmutation data became more convincing [22], it became obvious that the two models were inextricably linked. The first part of the puzzle was how to determine the possibility and probability of getting deep-orbit electrons. The classical papers on the subject indicated *transient* deep-orbit excursions and thus the possibility, but not necessarily sufficient probability, to solve the CF problem. Furthermore, the transient deep-orbit electrons did nothing to address the transmutation problem.

The relativistic Klein–Gordon and Dirac equations' prediction of deep-electron orbits did provide the means for CF results (including transmutation). Nevertheless, this aspect of the fundamental equations in quantum mechanics has been controversial for over 50 years. As mentioned above, in Section 2.5, there are reasons that the deep-electron levels are suspect. One non-mathematical aspect of the problem is population of the deep levels. If the deep levels *can* be populated, why do not we see evidence of the deep-orbit electrons and their transitions into these levels? Also, why do not all of the atomic electrons fall to these levels and the universe collapse? The answers to these questions are somewhat subtle, but never seem to appear in the literature.

The first reason for the low decay probability to the deep orbits comes most readily from quantum mechanics. The non-zero angular momentum atomic-electron orbitals do not overlap the nucleus (or the deep-electron orbits). Therefore, the transition probability between these states is negligible. The zero angular momentum atomic-electron orbital *does* overlap the nucleus and the zero angular momentum deep-electron orbits. The simple two-level QM calculation of relative populations is of the same order as the transition probability of the highly forbidden zero-zero transition. What is not considered is that the system in a solid-state environment is not two-level. While the thermal transition probability out of the deep level in a star gives a femto-atom lifetime exceeding a century, the lifetime of a femto-hydrogen atom (an atom with a deep-orbit electron) might be less than a pico-second before it fuses with a nucleus in the high-density environment. Thus, outside of the cosmological implications, many predictions using the two-level model are meaningless in the real world. It is sufficient to note that the negligible thermal-excitation rate from the deep orbit, along its calculated ratio relative to the decay rate from the atomic levels, eliminates the possibility of finding electrons in a deep level orbit if there is any other loss mechanism.

Even if cold fusion processes were to increase the decay probability to the deep orbits by a great many orders of magnitude and detection capabilities were available to sensitively measure electrons in these orbits inside a reactor, it is unlikely that the deep-level population could be detected. An isotopic measure of the accumulated transmutation products would be the most sensitive measure of this deep-orbit effect. Detection of radioactivity from transmutation would be the next most sensitive indication of cold-fusion and perhaps of deep-electron-orbit involvement. However, such characteristic radiation has not been observed, for reasons described below. The measure of the thermal output from a cold-fusion reaction is proof of the cold-fusion reaction, but not the process responsible.

A major stumbling block to the general acceptance of CF is the lack of a model for this non-standard process. A similar problem exists for models of populating the deep-orbits. In Section 4.3, two processes are mentioned that have been proposed to produce deep-orbit electrons. Just as the relativistic quantum mechanics equations provided a basis for the deep-electron explanation for cold fusion, relativity, as applied to the highly energetic electrons in close proximity to the nuclear Coulomb potential, provides a basis for the transition of atomic electrons to the deep-orbits.

4.1. Transmutation

The D-O-E model, created to explain the D+D $\Rightarrow$ ^{4}He CF results, was found to fit the H+H $\Rightarrow$ D results as well (via the p–e–p and p–e–e–p fusion processes) [23,24]. The observed heat generation by CF with protons, not just with deuterons, led to refinements of the D-O-E model to include deep-orbit electron formation of femto-atoms and femto-molecules [25]. These new neutral structures became a basis for transmutation without the known 'hard' radiation (particulate or photonic) characteristic of neutron activation processes [26,27]. The neutral structures are strong transmutants. The hydrogen femto-atom H# becomes equivalent to a 'fat' neutron in terms of its ability to penetrate an atom and nucleus. Likewise, the hydrogen femto-molecule H#$_2$ becomes equivalent to a di-neutron. The ^{4}He## femto-atom, as it decays to the ^{4}He ground state might be hard to distinguish from a femto-molecule D#$_2$. It acts as a neutral alpha particle until it ejects the D-O-E(s) (if it does so) in its final decay process to ground.

4.2. 'Preferred' transmutation pathways in CF

Neutron activation is an extremely well-characterized process. It is a low-incident-energy-particle process that has no Coulomb barrier with which to contend. However, it produces unique transmutations giving radio-nuclides with well-known decay processes that are not observed in CF. We have just mentioned femto-atoms and femto-molecules and referred to them as 'fat' neutrons, di-neutrons, and neutral alpha particles that have the same capacity to penetrate nuclei as do neutrons. How would they differ or mimic the neutron interactions? There are three main differences:

They provide a multi-body decay process rather than the two-body process of neutron activation. One or more components of the femto-particle can be fused with the target nucleus with the remaining components able to carry off the excess energies. This allows a preferred path rather than the forced path of neutron activation. The preferred path is almost always toward the most stable daughter product (which result often mimics the natural isotopic abundance of elements). This preferred path is generally away from fission, if that would have been the normal result of neutron insertion.

Both the PdD and NiH systems have been explored to display details and the consequences of this preference [26,27]. They have one or two deep-orbit electrons present in the incident particle and generally in the daughter product. As in the case of the D+D $\Rightarrow$ ^{4}He CF decay process [17], these D-O-Es provide a faster path to nuclear ground levels than photo-emission (gamma decay) and perhaps even faster than fragmentation. They also provide the proximate electron(s) necessary to greatly accelerate the weak interaction required to produce a neutron (e.g., via a p–e–p reaction), if that is the preferred path to greatest stability.

They can cause transmutation without adding kinetic energy to the target nucleus. The ability to add a deep-orbit electron to a nucleus, thereby changing a nuclear proton into a neutron in an accelerated weak interaction, and to carry off excess reaction energy with the other femto-atom/molecule components is unique. This mimics the (n, p) reaction and is a means of reducing/eliminating gamma decay from excited daughter products.

4.3. Energy transfer between nucleons and electrons decaying to deep-orbit

Based on unconfirmed reports of NiH-based CF (discounted by many) the D-O-E model contributes some ideas to the formation of conditions necessary for CF. One of the problems with the D-O-E model is the mechanism of populating the deep-orbit levels. The photon decay from H atomic-electron ground states to the deep-orbits is a highly forbidden 0–0 transition. A non-photonic energy transfer has been proposed based on doing work, rather than on photo emission. The lochon-model [28], where the lattice and sub-lattice phonon fields interact to form D^+ and D^- pairs, allows work to be done as the charged deuterons are drawn together. While this may not work for transitions to non-relativistic deep orbits in a pure $1/r$ Coulomb potential, it would be possible in practice because of relativity and the additional terms in the potential [5]. Similarly, the linear-H molecule model [24] would provide for a photon-free decay to the deep levels. In both cases, the potential energy of the system decreases with the electron gaining kinetic energy and the deuterons losing mass energy. This part is no different than the atomic-electron case, where photons are emitted to satisfy the virial theorem. However, now the required energy loss goes into atomic or ionic motion and relative position rather than into photonic energy.

4.4. Energy transfer between nucleons and deep-orbit electrons

Defkalion reported [29] a non-activity of ^{61}Ni as the only nickel isotope of the five they tested as pure isotopes (58, 60, 61, 62, and 64) that did not show excess heat generation. While trying to figure out a mechanism to explain the reported isotopic anomalies in these NiH CF results and remembering that atomic electrons can transfer energy with nuclear states by both photonic and non-photonic (e.g., internal conversion) means, one of the present authors (AM) looked at the different nuclei involved. Two differences observed (in http://www.nndc.bnl.gov/chart/) were the high total angular momentum ($J_{\mathrm{n}} = 3/2^{-}$) of the ground state and the low first excitation level (67 keV) of the odd isotope. The high angular momentum is thought to prevent or retard transmutation via a femto-atom to the next stable element or isotope. The difference in binding energy through a weak interaction to convert a proton into a neutron vs. that through formation of a femto-molecule is an order of magnitude. Both processes involve a deep-orbit electron interacting (binding) with a nucleon.

When Rossi's work, based on the Lugano experiment [30], reported a major isotopic shift to ^{62}Ni after an extended run starting with a natural isotopic abundance, this appeared to contradict the Defkalion results that would predict an accumulation of ^{61}Ni. However, in the deep-orbit electron model, the H# reaction with ^{61}Ni could be a 'choke' point of the proposed transmutation chain along the nickel isotopes. If that isotope became a halo nuclide of ^{61}Ni (^{61}Ni plus the femto-H, H#, forming a femto=molecule), then ^{61}Ni+H# would, under isotopic-mass analysis, look like ^{62}Ni (within about 10 MeV). The mass difference results from the difference in binding energy of the halo nuclide vs. that of the fused neutron. If this happened and the pseudo ^{62}Ni was long-lived in that reactive environment, its final slow decay (^{61}Ni+H# into ^{62}Ni) would leave that later isotope dominant in the residue. The proposed transmutation chain, increasing along the nickel isotopes, would leave the nickel lattice intact to continue the reaction until the end of the natural Ni isotope chain. At this point, the preferred transmutation paths of the heavier nickel isotopes (via ^{62}Ni + H# and ^{64}Ni + H#) are no longer to nickel, but to copper and then Zinc. Thus, an apparent contradiction between two experimental results could be resolved to confirm the D-O-E model for both results. If either or both of the experimental claims were to be false, it would not disprove the model. It would simply not confirm it. If either of the results were to be confirmed, then there are specific tests that could confirm the model.

4.5. Energy transfer between atomic electrons and nucleons

A second major isotopic shift reported from the Lugano experiment was that of lithium. The report of a dramatic shift between the naturally dominant ^{7}Li relative to ^{6}Li and the final result with ^{7}Li being greatly reduced appears anomalous. However, the 1$^{\mathrm{st}}$ excited state of ^{7}Li (at 478 keV) permits the possible energy transfer from an s-orbit atomic electron to a low-lying nuclear state. If an atomic electron can give up energy (by photonic or non-photonic means to excite the nucleus) then it can decay to a deep-electron orbit of either the ^{7}Li or the H. If the electron is now deeply-bound to the proton, then the resulting femto-H, H#, readily fuses with the ^{7}Li to become ^{8}Be that quickly fissions into two alpha particles. The resultant ^{4}He, as a gas, would probably not be measured in the isotopic analysis of the molten ash. If the deep-orbit electron is bound to the ^{7}Li, the resulting hybrid[a] (^{7}Li#) would act as a long-lived ^{7}He atom. It would take a very precise mass analysis to distinguish it from ^{7}Li and one with very high resolution to separate it from the strong ^{7}Li peak of the system. However, as a helium equivalent, a gas, it could escape or be thermally separated from the starting solid and measured. Needless to say, it would not appear in the experimental results reported for the solid ash. Thus, we have a third mechanism (along with the two mentioned in section 4.3) for the transition of an atomic electron into a deep-electron orbit.

4.6. Selective attraction of femto-atoms/molecules to radio-nuclides (nuclear remediation)

The ability of CF to not only produce heat from a nuclear source with little or no radioactivity but to reduce other radioactivity that might be present has been a theme that seems to be too-good-to-be-true. Therefore, claims to observe this effect have been generally disregarded. Nevertheless, if it is true, can it be explained? The deep-orbit-electron model, because of the relativistic velocities and extreme accelerations of electrons in femtometer orbits, provides for

[a]While the proposed hydrogen or helium atoms with one or two deep-orbit electrons respectively form femto-atoms, we have not decided on how to name or clearly identify atoms with *both* deep-orbit and atomic-orbit electrons.

intense long-range electric fields at nuclear frequencies [18]. The consequence of these fields and their interactions is the ability of the D-O-Es to transfer energy from the nucleus to the lattice and to interact with nuclear components at many lattice spacings from the source. The resonant-energy transfer from excited nuclei to a D-O-E or the lattice will provide a long-range attractive force between a femto-atom and the radio-nuclide. This force will be much stronger and further-reaching than that of the $1/r^6$ dependent induced-dipole-induced-dipole, interaction between a femto-atom and a stable nucleus. Thus, the small and mobile femto-atom experiences a selective attraction to radio-active nuclei and can become important in nuclear remediation. The D-O-E model is able to explain things that no other model can. There is still concern that some of these phenomena are not real. It will take time to sort out and reproduce the data before refinement and testing of the model becomes possible.

5. Summary

Known and proposed physical bases for, and the consequences of, the *mathematical predictions* of deep orbits:
Special relativity leads to:

- deep-electron levels with high binding energy ,
- mass changes (real and effective) for the nucleons and deep-orbit electrons,
- enhanced Coulomb and interaction potentials.

Spin-axis precession(s) leads to:

- the deBroglie wavelength and frequency for linear motion,
- a new higher-frequency 'mode' for wave mechanics of tightly bound electrons,
- a deep-orbit quantum number, k, for the new mode,
- deep-level splitting from spin–orbit, spin–spin, momentum, and magnetic interactions.

Effects of deep-orbit electrons (D-O-Es):

- D+D fragmentation ratios – D-O-Es reduce the mass and repulsive energy of nuclear protons to allow D+D $\Rightarrow$ ^{4}He$^{\#}$ as preferred reaction,
- a 'fast' nuclear decay process – proximity coupling of D-O-Es with excited nucleons speeds decay rate, but reduces photonic decay (by both perturbation and competition),
- transmutation – near-total 'screening' of H$^{\#}$ and ^{4}He$^{\#}$ by D-O-Es gives 'fat' neutrons and 'neutral alphas', which can readily penetrate atoms and nuclei,
- femto atoms – a D-O-E will make an atom with atomic number Z act as one with $Z-1$, etc.

Effects of D-O-E femto-products:

- femto-atoms can combine to form neutral femto-molecules. Together, with their ions, these form the femto-products,
- p–e–p $\Rightarrow$ d: The 3-body p–e–p problem is reduced to 2-body problem, a proton and a neutral femto-hydrogen atom (p + H#). This greatly enhances the probability of such a reaction,
- D-D = d–e–e–d $\Rightarrow$ ^{4}He$^{\#}$: Lochon mechanism (locally bound electron pair) reduces a 4-body to a 2-body interaction (D–D $\Rightarrow$ D# + D# $\Rightarrow$ ^{4}He$^{\#}$). This greatly enhances the probability of such a reaction,
- 'preferred' transmutation pathways in CF: femto-atoms or femto-molecules break up on entering a nucleus; assuming angular momentum conservation, the multiple options allow 'motion' toward the greatest nuclear stability (the lowest energy state),

- transmutations without 'hard' radiation: femto-products have relativistic D-O-Es that out-compete gamma decay for removing any excess energy from a nucleus.

Effects of relativistic D-O-Es:

- nuclear energy transfer to lattice electrons: relativistic bound electrons have extremely high, bound, EM fields. D-O-Es act like photons as intermediary between nucleus and lattice,
- D-O-E energy transfer to and from nearby nuclei: by proximity coupling and strong EM fields with nucleon-comparable frequencies; (like internal conversion and its inverse),
- selective attraction (nuclear remediation): D-O-E lowering of an excited-nucleus energy will create an attractive force ($F = -\mathrm{d}V/\mathrm{d}x$),
- atomic-electron energy transfer to nucleus: Resonant EM coupling will excite low-energy nuclear levels and allow the decay of atomic electron to deep-orbit levels. This would be the reverse of internal conversion where an atomic electron absorbs nuclear energy.

We have shown, mathematically and physically (in the accompanying ICCF-20 presentations [5,31]), that the prediction of deep-orbit electrons cannot be rejected. These levels are based on relativistic effects associated with the near-field interactions of electrons and nuclei.

If the deep levels really exist and can be populated, they provide the basis for understanding cold fusion and its many experimental observations. They also provide physical concepts that are the basis for new fields of study (femto-physics and femto-chemistry).

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References

[1] J.A. Maly and J. Va'vra, Electron transitions on deep Dirac levels I, *Fusion Sci. Technol.* **24**(3) (1993) 307–318, http://www.ans.org/pubs/journals/fst/a_30206.

[2] R. Rice, Y. Kim and M. Rabinowitz, Comments on electron transitions on deep Dirac levels I, *Fusion Technol.* **26**(1) (1994) 110. And *Response* by Maly and Va'vra, *Fusion Technol.* **26**(1) (1994) 111.

[3] R. Rice, Y. Kim, Rabinowitz and Zubarev, Comments on exotic chemistry models and deep Dirac states for cold fusion, *Proc. 4th Int. Conf. on Cold Fusion*, Vol. 4, Dec. 6–9, Hawaii, 1993, p. 4.1, *lenr-canr.org/acrobat/RiceRAcommentsona.pdf*ý, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-104188-V4.

[4] F. Wilczek, Origins of Mass, arXiv:1206.7114v2, 22 Aug. 2012.

[5] J.L. Paillet and A. Meulenberg, Advance on Electron deep orbits of the hydrogen atom for LENR, *Proc. of ICCF-20, the 20th Int. Conf. on Condensed Matter Nucl. Sci.*, Sendai, Japan, October 2–7, 2016.

[6] Abd ul-Rahman Lomax, Replicable cold fusion experiment: heat/helium ratio Current Science,25 February 2015, 108–104) http://www.currentscience.ac.in/php/feat.php?feature=Special%20Section:%20Low%20Energy%20Nuclear%20Reactions&featid=10094.

[7] A. Meulenberg and K.P. Sinha, New visions of physics through the microscope of cold fusion invited paper, *17th Int. Conf. on Condensed Matter Nucl. Sci.*, Daejeon, Korea, 12–17 August, 2012, *J. Condensed Matter Nucl. Sci.* **13** (2014) 378–390.

[8] A. Meulenberg, Extensions to physics: what cold fusion teaches, Special Section: Low Energy Nuclear Reactions, Section editors: M. Srinivasan and A. Meulenberg, *Current Sci.* **108**(4) (2015) 25,

http://www.currentscience.ac.in/cs/php/feat.php?feature=Special%20Section:%20Low%20Energy%20Nuclear%20Reactions&featid=10094.

[9] E.K. Storms, *The Explanation of Low Energy Nuclear Reaction*, Infinite Energy Press, Concord, NH, 2014, 365 pages (updated e-version available at Amazon.com).

[10] A. Meulenberg and K.P. Sinha, Tunneling Beneath the ^{4}He$*$ Fragmentation Energy, presented at *239th ACS National Meeting*, San Francisco, CA, March 2010, *J. Condensed Matter Nucl. Sci.* **4** (2011) 241–255.

[11] A. Meulenberg, Pictorial description for LENR in linear defects of a lattice, *ICCF-18, 18th Int. Conf. on Cond. Matter Nucl. Sci.*, Columbia, Missouri, 25/07/2013, *J. Cond. Matter Nucl. Sci*. **15** (2015) 106–116.

[12] E.K. Storms, A theory of LENR based on crack formation, *Infinite Energy* **19** (2013) 24–27.

[13] A. Meulenberg, Deep-orbit-electron radiation absorption and emission, *ICCF-18, 18th Int. Conf. on Cond. Matter Nucl. Sci.,* Columbia, Missouri, 25/07/2013, *J. Condensed Matter Nucl. Sci.* **15** (2015) 125–136.

[14] J. Schwinger, Nuclear energy in an atomic lattice, in *The First Annual Conf. Cold Fusion*, Salt Lake City, Utah, 1990.

[15] K.P. Sinha, A theoretical model for low-energy nuclear reactions in a solid matrix, *Infinite Energy* **29** (2000) 5, 29, 54.

[16] A. Meulenberg and K.P. Sinha, Deep-electron orbits in Cold Fusion, *17th Int. Conf. Condensed Matter Nucl. Sci.*, Daejeon, South Korea, 12–17 August, 2012, *J. Condensed Matter Nucl. Sci.* **13** (2014) 368–377.

[17] A. Meulenberg, From the naught orbit to He^4 ground state, *16th Int. Conf. on Condensed Matter Nucl. Sci.*, Chennai, February 6–11, 2011, *J. Condensed Matter Nucl. Sci.* **10** (2013) 15–29.

[18] A. Meulenberg and K.P. Sinha, Deep-orbit-electron radiation emission in decay from ^{4}He*# to ^{4}He, *17th Int. Conf. Condensed Matter Nucl. Sci.*, Daejeon, South Korea, 12–17 August, 2012, *J. Condensed Matter Nucl. Sci.* **13** (2014) 357–368.

[19] T.H. Boyer, Unfamiliar trajectories for a relativistic particle in a Kepler or Coulomb potential, *Am. J. Phys.* **72**(8) (2004) 992–997.

[20] J. Chen, Trajectories for a relativistic particle in a Kepler potential, Coulomb potential, or a scalar field, Senior research thesis, (2005), College of William and Mary,
http://www.wm.edu/as/physics/undergrad/major/seniorhonors/previoustheses/2005/index.php (click on Chen).

[21] George H. Miley, Summary of the transmutation workshop held in association with ICCF-14, *Proc. 14th Int. Conf.*, August 2008, Washington, DC, Vol. 1, pp. 212–216, https://www.iscmns.org/iccf14/ProcICCF14b.pdf

[22] M. Srinivasan, G. Miley and E. Storms, *Low-Energy Nuclear Reactions: Transmutations*, Nuclear Energy Encyclopedia. Ch. 43, S.B. Krivit and J.H. Lehr (Eds.), Wiley, New York, 2011, ISBN 978-0-470-89439-2, http://lenr-canr.org/acrobat/Srinivasanlowenergyn.pdf.

[23] A. Meulenberg and K.P. Sinha, Composite model for LENR in linear defects of a lattice, *ICCF-18, 18th Int. Conf. on Cond. Matter Nucl. Sci.*, Columbia, Missouri, 25/07/2013, Proceedings at http://hdl.handle.net/10355/36818.

[24] A. Meulenberg, Pictorial description for LENR in linear defects of a lattice, *ICCF-18, 18th Int. Conf. on Cond. Matter Nucl. Sci.*, Columbia, Missouri, 25/07/2013, *J. Cond. Matter Nucl. Sci.* **15** (2015) 106–116.

[25] A. Meulenberg and J.L. Paillet, Basis for femto-molecules and -ions created from femto-atoms, *ICCF-19, 19th Int. Conf. on Cond. Matter Nucl. Sci.*, Padua, Italy, 15/05/2015, *J. Condensed Matter Nucl. Sci.* **19** (2016) 202–209.

[26] A. Meulenberg, Femto-helium and PdD Transmutation, *ICCF-18, 18th Int. Conf. on Cond. Matter Nucl. Sci.*, Columbia, Missouri, 25/07/2013, *J. Condensed Matter Nucl. Sci*. **15** (2015) 117–124.

[27] A. Meulenberg, Femto-atoms and Transmutation, 17th International Conference on Condensed Matter Nuclear Science, Daejeon, Korea, 12-17 August, 2012, J. Condensed Matter Nucl. Sci. 13 (2014), 346-357

[28] K.P. Sinha and A. Meulenberg, A model for enhanced fusion reaction in a solid matrix of metal deuterides, *Proc. 14th Int. Conf. Condensed Matter Nucl. Sci*. and *the 14th Int. Conf. Cold Fusion (ICCF-14)*, 10–15 August 2008, Washington DC, p. 633,
https://www.google.com/url?q=http:lenr-canr.org/acrobat/NagelDJproceedinga.pdf&sa=U&ei=YBB4U7_dCpXg8AXlsYGQAg&ved=0CAsQFjAE&client=internal-uds-cse&usg=AFQjCNF7Qd6sCPj15UEA8vj6ZaM7pPKzSw

[29] J. Hadjichristos, M. Koulouris and A. Chatzichristos, Technical characteristics and performance of the Defkalion's hyperion pre-industrial product, *17th Int. Conf. Condensed Matter Nucl. Sci*., Daejeon, South Korea, 12–17 August, 2012,*J. Condensed Matter Nucl. Sci.* **13** (2014).

[30] G. Levi et al., Observation of abundant heat production from a reactor device and of isotopic changes in the fuel,

www.sifferkoll.se/sifferkoll/wp-content/uploads/2014/10/LuganoReportSubmit.pdf.
[31] A. Meulenberg and J.L. Paillet, Physical reasons for accepting the Deep-Dirac Levels, *Proc. of ICCF-20, the 20th Int. Conf. on Condensed Matter Nucl. Sci.*, Sendai, Japan, October 2–7, 2016.

Appendix: Mass Changes for Atomic Nuclei

Atomic mass change, as a result of photo-emission, is well accepted. Mass change of the proton, but not of the electron, is not a 'given' and is never discussed. However, it can be accommodated in the concept of energy conservation and "which body does work." Consider a hydrogen atom:

- $W = \mathbf{F} \cdot \mathbf{d}$ = force times distance.
- The electrostatic force **F** is the same on both bodies.
  - Both electron and proton contribute to the electric field energy and thus the force. Equally?
  - Force and field energy both increase as the proton and electron move together.
- The proton moves the electron, but the electron has little kinematic effect on the proton.
- The distances moved indicate that more work is done by **E**-field on electron than on proton. However,
- Field energy and electron energy and mass all are known to increase as work is done on electron to bring it closer to proton. What contributes most (or all) of this energy?
- No separate measure of proton mass change has been made. (Is this true?)
- Nevertheless, the proton is the only 'uncommitted' ultimate source of energy for the emitted photon and for the increase in field and electron-mass energy.

QED, the proton mass must decrease as the electron photo-decays toward the ground state.

This concept is critical to the model of "fusion beneath the fragmentation level" [10]. Motion as a whole will increase the electron mass (by relativistic distortion of the Coulomb field and the resultant magnetic-field energy). How does the proton change its rest mass? A strong external field (from the deep-orbit electron) will alter the internal quark relationships of a nucleon (e.g., by polarization and alteration of their interaction distances). While in theory the effect could be both an increase and a decrease in energy levels (e.g., the Stark effect in atomic electrons), in this situation, the lower-energy levels are predominantly occupied to lower the total nucleon energy and mass.