Cold Fusion Nuclear Reactions

Horace Heffner December, 2009

DEFLATION FUSION

The field of cold fusion (CF), the fusion of hydrogen in a metal lattice, as discovered by Fleischmann and Pons, has been expanded to include the general class of nuclear reactions which can be initiated in low temperature environments, and named the field of low energy nuclear reactions (LENR).[1] A large number of peer reviewed papers and books have been published in this field.[2 3 4 5 6 7] Extensive development continues, as do mysteries regarding various mechanisms of the experimentally well documented effects.[8 9]

Any theory that is to describe LENR has to explain not only how the Coulomb barrier is breached, why high energy particles and gammas are not seen from hydrogen fusion reactions, and why the branching ratios are so skewed, but also why almost no signature, including heat, is seen corresponding to nuclear mass changes from heavy lattice element transmutation. It appears unlikely all these things can be simultaneously explained without the presence of one or more catalytic electrons in the mix which highly *de-energize* the fused nucleus. This is especially true of heavy element transmutation, which produces very little in the way of high energy signatures that could be expected from the quantity of events and the observed nuclear mass changes.[10 11 12 13 14 15 16 17 18 19 20] If a nucleus is not highly energized to begin with, then there is no need to figure out how high energy products are absorbed by the lattice, a common problem to LENR theory. It has been proposed that all the above requirements can be met by electron catalyzed fusion via a process called deflation fusion.[21 22] Deflation fusion is a process whereby a ground state electron bound close to a hydrogen nucleus for attosecond periods, but with small wavelength, the deflated state hydrogen, makes breaking the Coulomb barrier feasible. Though the deflated state of hydrogen exists briefly, it exists frequently. The electron kinetic plus potential energy remains at the energy of the electron in the chemical environment in which the hydrogen resides, i.e. the sum of kinetic plus potential energy is the same in both the deflated and chemical states, as they are degenerate forms of the same state.

The following is a brief review of the deflation fusion mechanisms and process:

1. The deflated state is made probable by the status of the chemical environment, e.g. by special lattice conditions for absorbed hydrogen,

2. The *joint* tunneling probability of the hydrogen nucleus and electron in deflated

state into any nucleus is much larger than the probability of the hydrogen nucleus alone. In a conceptual sense, if an electron briefly precedes a positive hadron into a hydrogen nucleus then there is no barrier for the hadron to follow. However, this is energetically not as feasible as a joint tunneling because when a joint tunneling occurs there is minimal change in local field energies if the point of origin of the jointly tunneling electron and hadron is the same. Joint small wavelength electron plus hydrogen nucleus tunneling makes the possibility of observable quantities of heavy lattice element transmutation feasible. This is the primary heavy nucleus LENR process.

3. The deflated state hydrogen is neutral to any hydrogen nuclei diffusing through a lattice by tunneling. It thus presents no Coulomb barrier. Deflated state hydrogen is located where its ordinary state nucleus is located, at lattice site potential well locations, and thus at the precise locations to which the diffusing hydrogen tunnels.[23] Fusion results due to the proximity of the post tunneling nucleus and the deflated nucleus. This is the primary CF process.

4. Once the Coulomb barrier is overcome through the catalytic effect of the electron, fusion occurs due to the strong force. As a result of fusion, the charge of the nucleus to which the electron is bound suddenly multiplies, while the kinetic energy of the electron remains initially constant. This greatly reduces the electron's potential energy and de-energizes the resulting fused nucleus. The electron is trapped by a reduction of kinetic plus potential energy of MeV magnitude. The amount of energy lost by the process, $(Z-1)\ (1.44 \times 10^{-9}\ \text{ev m}) / r$, is a function of the charge of the newly formed nucleus charge and its radius, which is a random variable.

5. The trapped nucleus expands, its wavefunction size inflated by uncertainty energy, zero point energy, as does the electron wavefunction. However, while trapped in the nucleus for an extended time by a deficit of kinetic plus potential energy, the electron radiates, creating a cascade of gammas in the EUV or soft x-ray range.

The probability of the existence of the deflated state in a plasma is negligible, thus it has no relevance to hot fusion. However, the lattice half-life to fusion of the deflated state is much smaller than the lattice half-life to fusion of a bare hydrogen nucleus. Deflated state hydrogen fuses in observable quantities for obvious reasons even though there is (a) no sub-ground state energy of hydrogen initially involved, and (b) no pre-fusion neutron generation involved. These are the primary ways in which deflation fusion theory differs from other cold fusion theories. There is thus

(1) no need to explain how a sub-ground state hydrogen is formed in a lattice, (2) no need for large sub-ground state binding energies to overcome the Coulomb barrier, (3) no need to explain how neutrons in the lattice are generated en mass and yet not readily detectable directly or through neutron activation of materials in the lattice, or (4) to explain how the high energy barriers of high mass lattice elements are also defeated. There is also (5) no further need to explain why there is a lack of high energy gamma signatures or to (6) explain how MeV magnitudes of reaction energy is carried off by phonons or through simultaneous action of large bodies of lattice atoms, or why (7) large numbers of high kinetic energy particles are not detected or why (8) readily observable high energy bremsstrahlung are not seen.

Though EUV and soft x-ray radiation from an electron trapped in a nucleus is expected, it is also notable that infrared radiation corresponding to excess heat has been detected.[24] [25] The source of such radiation could be due to combined motions of the nucleus and electron, or conversion of trapped electron kinetic energy to phonons and lattice heat.

What follows is a further examination of the deflation fusion process and the deflated state itself, especially the nature of the initial deflated state, with a proposal of the possible role of the up quark in this state, and the possible role of strange and anti-strange quarks in signature event creation. It is an exploration of the many kinds of nuclear reactions that might be associated with cold fusion, however rare they may be.

THE LOST FIELD ENERGY

Other theories have proposed electron deuteron tunneling as a mechanism for cold fusion.[26] However, deflation fusion theory differs in that it predicts a change in the excited fused nucleus energy, a de-energized nucleus.

Field energy is lost to the vacuum in the initial phase of deflation fusion. This loss of energy, the MeV order de-energizing of the nucleus, accounts for extreme changes in branching ratios for the fused nucleus. The sum of potential energy U(r) plus kinetic energy E(r) of the deflated state is the same as the ground state at all r, thus:

$$E(r) + U(r) = E_{ground}$$

at all times. The potential energy of a single electron orbiting a nucleus with charge Z, taken with respect to the electron at infinity is:

$$U(r) = k\,(Z^*q)(-q)(1/r) = -k\,Z\,q^2/r$$

and for a hydrogen atom:

$$U(r) = -k\,q^2/r$$

If a fusion is the result of tunneling then the radius of the electron at that instant is unchanged, as is its momentum, and kinetic energy E(r). However, the nucleus now has a new charge Z, not charge +1. The electron has a new potential energy S(r):

$$S(r) = -k\,Z\,q^2/r$$

and a new total energy T(r):

$$T(r) = E(r) + S(r) = [-U(r) + U_{ground}] + S(r)$$

There has been a change in the total energy of the system ΔE given by:

$$\Delta E = T(r) - U_{ground} = [-U(r) + U_{ground} + S(r)] - U_{ground} = S(r) - U(r)$$

$$\Delta E = [-k\,Z\,q^2/r] - [-k\,q^2/r] = -k\,(Z-1)\,q^2/r$$

$$\Delta E = -(Z-1)\,(1.44 \times 10^{-9} \text{ ev m}) / r$$

For example, if $r = 1.4 \times 10^{-16}$ m for DD fusion, then Z=2 and:

$$\Delta E = -(2-1)\,(1.44 \times 10^{-9} \text{ ev m}) / (1.4 \times 10^{-16} \text{ m}) = -10.3 \text{ MeV}$$

If a Pd nucleus is fused then the resulting Z = 47, and r = 1.76x10^-9 m, then:

$$\Delta E = -(47-1)\,(1.44 \times 10^{-9} \text{ ev m}) / (1.4 \times 10^{-16} \text{ m}) = -473 \text{ MeV}$$

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BRANCH RATIO VARIANCE

If any byproduct of a fusion event, such as a neutron, is formed on a stochastic basis, i.e. having energy or observed frequency representing a sample from a random distribution, then other products of the same fusion process must also be forming on a stochastic basis. Descriptions of such events and products then are best specified using probability distributions, i.e. stochastic variables. The proportions of product types produced from fusion are random variables, thus indicating underlying stochastic processes. The proportions of byproducts produced from given inputs to fusion events, i.e. the branching ratios, are stochastic variables affected by the environment and circumstances in which the fusion occurs. One of the most distinguishing differences between hot and cold fusion are their branching ratios, the probabilities of each reaction pathway. It is well known that in deuteron-deuteron fusion, (DD fusion) that the D(D,p)T and D(D,n)He3 reactions are suppressed in the cold fusion variety of reactions, leaving the D(D,gamma)He4 reaction to dominate, but with the gamma energy released in small difficult to detect increments, possibly spread throughout the condensed matter lattice which makes cold fusion possible. The energy released by cold fusion is thus difficult to measure except through calorimetry.

The varying of the branching ratios for DD reactions, between hot and cold fusion, indicates stochastic variables are at work in the process. A key variable is the mean net reaction energy. In order to suppress the D(D,p)T and D(D,n)He3 reactions, and drive most everything toward the D(D,gamma)He4 reaction, the mean energy available from cold fusion must be offset in the negative direction from that available from purely kinetic fusion. We can see this from the energy available from each of the hot fusion branches:

D(D,p)T 4.03 MeV
D(D,n)He3 3.27 MeV
D(D,gamma)He4 23.8 MeV

If the D(D,gamma)He4 branch is highly favored and the D(D,p)T and D(D,n) He3 reactions highly suppressed, it is reasonable to expect the lower energy branches are being energetically suppressed by a lack of energy to make them feasible. This requires an energy deficit to occur in the combined intermediate reaction state designated here as He*. He* is the intermediate state just prior to branch selection mechanics taking effect. Highly suppressing both the D(D,p)T and D(D,n)He3 reactions requires a mean energy deficit greater than 4 MeV.

Assume for a moment the energy of He* in a cold fusion reaction in specific lattice conditions is somehow offset by a random variable $E(E_{mean},s)$ having a distribution with mean E_{mean} standard deviation s, and variance s^2, which are functions of the environment and circumstances of the reaction, and E_{mean} is a negative number, an energy deficit. That is to say the branch selected is determined or limited in frequency by energy $Q' = Q + E(E_{mean},s)$, where $E(E_{mean},s)$ is due to the circumstances of the reaction and E_{mean} is negative.

$E(E_{mean},s)$ relates to cold fusion reactions, and therefore $E(E_{mean},s)$ is not related to any *initial* high energy kinetics of the reactants. Further, $E(E_{mean},s)$ results from energy transactions with the vacuum, and varies across time throughout the reaction, and may result in an apparent violation of conservation of energy at the completion of the reaction. The energy variability, as described by the magnitude of s, arises from vacuum phenomena. In part it arises from the nuclear temperatures of the inputs to the reaction, which have Boltzmann distributions. Nuclear temperatures are sustained by uncertainty energy. Beyond this input variability, an additional mechanism has been proposed to cause variability, the size of the He* that results from the tunneling and wave function collapse that results in cold fusion, which is in part a function of the states prior to wave function collapse.

An additional variability in the apparent net reaction energy is the amount of nuclear heat initially in the reaction products. It is notable that the heat in the input nuclei adds to the net energy of the reaction, while the heat in the product nuclei and the heat given to the vacuum, in the fusion producing wave function collapse, subtract from the net energy of reaction, but all these factors contribute to the variability of the reaction energy s.

Suppose the post fusion nucleus from a given process has a mean deficit of 6 MeV from the hot fusion 23.8 MeV. The energy to permit the D(D,p)T or D(D,n)He3 reactions is typically then not available. Assume the He4* activated nucleus created upon fusion has a mean energy of 23.8 MeV embodied in the thermalized motion of the constituents: two neutrons, two protons, and an electron. The highly nonlinear motion of the constituents places various amounts of strain on each of the bonds until some energy is radiated away and the process continues, or one or more of the bonds is broken and reaction products result. Under this assumption the bond breaking energy to enable the D(D,p)T reaction is 23.8 MeV - 4.03 MeV = 19.8 MeV. Similarly the bond breaking energy to enable the D(D,n)He3 reaction is 23.8 MeV - 3.27 MeV = 20.5 MeV. If in this given environment we suppose the catalytic electron creates an energy deficit $E(E_{mean},s)$, where E_{mean} = -6 MeV, and s = 0.5 MeV, then the mean deficit for the D(D,p)T reaction is 6 MeV - 4.03 MeV ~= 2 MeV, or about 4 s. Similarly the bond breaking energy to enable the D(D,n)He3 reaction requires 6 MeV - 3.27 MeV ~= 2.75 MeV or about 5.5 s. Tritium production would be a 4 sigma exception event, and neutron production would be a 5.5 sigma exception event. The proportion P(D(D,n)He3) of D(D,n)He3 events given the reactions is an N sigma event is given by[27] :

P(D(D,n)He3) = P(N) = erfc(N/sqrt(2))/2 = erfc(5.5/sqrt(2))/2 = 1.90 x 10^{-8}

Similarly:

P(D(D,p)T) = erfc(4/sqrt(2))/2 = 3.17 x 10^{-5}

and the ratio of tritium events to neutron events is 1.67x10^{3}. If s is just 75% the size, or 3.75 MeV,we have:

P(D(D,n)He3) = erfc((5.5/0.75)/sqrt(2))/2 = 1.12 x 10^{-13}

P(D(D,p)T) = erfc((4/0.75)/sqrt(2))/2 = 4.82 x 10^{-8}

and the ratio of tritium to neutron events is 4.3 x 10^{5}.

Of further use is the ability to compute sigma given the probability P of an event, using the erfc inverse function $erfc^{-1}$, or in Mathematica notation, erfc^-1. For example given P = 4.82x10^{-8}, we have:

σ = erfc^-1(2*P)*sqrt(2) = erfc^-1(2*(4.82x10^-8))*sqrt(2) = 5.33

Noting that 5.33 = 4/0.75, we can see we have reversed the computation of the D(D,p)T reaction values above. The author has also found the function

σ = (-ln(P)*1.019)^0.57637

useful for estimating σ within about 4% error, given P the probability of an upside tail excursion, for σ in the range of 3 to 15, i.e. P in the range $1.3\text{x}10^{-3}$ to $3.6\text{x}10^{-51}$.

For example:

σ = (-ln(4.82x10^-8)*1.019)^0.57637 = 5.15

And σ = 5.15 is within 3.4% of the correct value given above, σ = 5.33.

Despite the nuclear energy deficit affecting the branching ratio, the catalytic electron wave function can be expected to expand until it can occupy a chemical energy sized orbital. It can also radiate energy in the process. The energy for the expansion and radiation is supplied by a combination of the action of the zero point field and fusion energy. The energy lost via initial field energy loss upon fusion is at least in part returned from the vacuum. It is also feasible that vacuum transactions, such as the creation of neutrinos, can siphon off trapped electron energy, and thus some of the final heat detectable by calorimetry. Therefore, the deficit E_{mean} can not be determined precisely simply by measuring the enthalpy of cold fusion reactions. However, knowing the branching ratios in a given environment provides a means of at least estimating E_{mean} and s. It is notable that slight changes in either E_{mean} or s can result in dramatic effects on the observed branching ratios.

Note that the average energy deficit does not have the same negative magnitude, i.e. E_{mean} is not a large negative value, in hot fusion reactions because in hot fusion there is no electron in the excited He* intermediate product reducing the amount of available potential energy. A catalytic electron has an influence on both the kinetic and potential energy of the nucleus, and this influence varies with time due to vacuum energy transactions. In addition, the electron present in the resulting fused nucleus permits it to radiate energy in small increments, thus avoiding a single large gamma.

The lattice is important to cold fusion because it creates an environment where the electron can have a high frequency of occurrence in the nucleus. Cold fusion in a vacuum or plasma environment is unlikely because the deflated state, the electron in the hydrogen nucleus, exists too briefly for the kinetic approach of a charged nucleus to the deflated nucleus or vice versa. The deflated state is too brief to provide electron catalysis for high energy vacuum collisions except at energies so extreme fusion is otherwise expected. The deflated state might be created with significant frequency in a plasma magnetic pinch with sufficient current density.

Deflated state particles, being neutral, have only magnetic energy, dipole attraction, to make their long range tunneling feasible, thus when they tunnel their most likely targets are the much closer lattice nuclei, which present no Coulomb barrier to them. The catalytic electrons in that case, i.e. the case of heavy element transmutation LENR, should tend to end up undergoing a weak reaction, so the event amounts to a one or two neutron addition to the lattice element, for protium or deuterium respectively. Lattice site to lattice site hydrogen tunneling in heavily loaded lattices is Coulomb repulsion driven by forces between adjacent sites, which includes forces due to lattice distortion around occupied sites. The sites to which hydrogen atoms are driven to tunnel to are either unoccupied by hydrogen or momentarily occupied by deflated state hydrogen. There is thus typically only one catalytic electron per fusion.

In the deflated state the electron has the kinetic energy to hop back to its chemical energy orbital existence, i.e. coexists with that existence. However, if a deuteron tunnels to close proximity to a deflated state deuteron, fusing, the charge of the nucleus just doubled. The electron is now energetically trapped in the deflated state. The energy it subtracts from the nucleus depends on the distance of the electron from the nucleus at the time of the collapse, i.e. its size, which is a random variable.

If we know $E(E_{mean},s)$ from branching ratios, we can estimate the mean size of the nucleus after initial fusion events. Given

$$E_{mean} = \Delta E = (Z\text{-}1)\ (1.44 \times 10^{-9}\ \text{ev m}) / r$$

we have:

$r = \Delta E = (Z\text{-}1)\ (1.44 \times 10^{-9} \text{ ev m}) / \Delta E$

and for $\Delta E = 6$ MeV we have

$r = (1.44 \times 10^{-9} \text{ ev m}) / (6 \text{ MeV})$

$r = 2.4\text{x}10^{-16}$ m

Note that this is *not* the expected radius at the moment of wavefunction collapse. That size can be effectively zero, or small enough to essentially remove all the energy of fusion, which is returned only by the process of electron radiation and nucleus expansion and zero point field interaction. The above radius is the electron wavefunction radius at which the Coulomb potential of the electron-nucleus combined wavefunction begins to affect the branching ratio.

It is notable that, assuming the deuterons added to heavy elements are in the deflated state, and the average electron location is 0.85 or less of the newy fused atomic radius, then in some cases[28] the binding energy of the included electrons makes feasible holding the newly fused heavy isotope together long enough to fission.

The deflated state may not be a true "state" at all in the conventional sense. It is merely easy to conceptualize in that fashion. Quantum wavefunctions only speak of potentialities for existence with associated probabilities, not necessarily true existence. In the lattice the deflated state is a dual state with the orbital state. It merely has some probability of being observed upon wave function collapse. There may even be no observable velocity or duration for change of state. The same might be said for the fusing of the nuclei. Prior to the fusion, the possibility of the fusion may only be a potentiality that manifests with some probability. The wave function collapse itself is clearly theoretically likely to be able to appear to exceed the speed of light, because the quantum wave function of a particle theoretically extends to infinity. The particles involved are already “there” with some probability. Only the *effects* of the collapse, such as changes in the Coulomb field, necessarily expand at light speed or less. If the lattice constant is 3.89×10^{-10} m, as it is for Pd at room temperature, then time for information that the nucleus charge is diminished travels to an adjacent site in time τ given by:

$\tau = (3.89 \times 10^{-10} \text{ m})/c = 1.3\times10^{-18} \text{ s} = 1.3$ attoseconds

Lattice constants below 3 Å result in τ less than an attosecond. The lattice constant of the chosen lattice material is thus critical to permitting enough time for incoming hydrogen to react to the target hydrogen as masked.

It may take string theory to fully understand cold fusion. However, it is fairly easy to understand how electron catalysis reduces the mean energy available from fusion, and how that affects the branching ratio of cold fusion vs hot fusion. The effect of the catalytic electron is difficult to detect in DD fusion reactions. However, manifestations of the difference in $E(E_{mean},s)$ in cold fusion reactions may be revealed in tritium fusion, e.g. DT reactions, because high energy neutrons are always produced, high enough energy that their energy spectrum should reveal the presence of a negative E_{mean} resulting from electron catalyzed fusion. Adding a small amount of tritium to heavy water CF experiments should therefore provide a large increase in neutron signatures and a very clear indicator of when and how much actual fusion is occurring.

THE UP QUARK AS DEFLATION NUCLEATOR

Even in the deuteron or triton, the proton might be assumed to be the focus, the nucleator, of the electron deflated state, because it is the only hadron with a positive charge. However, the neutron is also a candidate for nucleating the deflated state. The up quark, being the positive quark type in both the proton and neutron, present singly in the neutron or as a pair in the proton, must necessarily be the ultimate nucleator of the deflated state in an ordinary hydrogen nucleus. A rough estimate calculation has been made showing the feasibility of at least a momentary up quark plus electron bound state (u e)* within the proton or neutron, thus creating a (p e)*, (D e)* or (T e)* state in the protium, deuterium, or tritium nucleus in which the deflated hadron resides.[29] This calculation demonstrates that, ironically, the more collapsed, i.e. the smaller, the deflated portion of the electron wavefunction leading to cold fusion, the higher the field densities and potential for high energy vacuum exchanges, high mass virtual particle formation, and weak interactions. Such weak interactions are not probable within the degenerate deflated hydrogen state, because it is unstable and too brief. However, following combining with another nucleus by tunneling, the greatly de-energized resulting fused nucleus with trapped electron provides added time for weak reactions to occur. Various candidate reactions have been described in Giancarlo Gazzoni's article on electroweak interactions as they apply to cold fusion and half-life reductions.[30] These reactions, or other electron involved reactions, especially in a highly de-energized nucleus, result in low energy gammas, which are characteristic of cold fusion reactions.

STRANGE QUARKS

A wide variety of reactions are made possible by the frequent presence of strange quark pairs, created periodically and momentarily from the vacuum, inside the proton and possibly the neutron.[31] The positive anti-strange quark can also act as a momentary nucleator for the deflated state. It is well known that the atomic Coulomb potential well has a large effect on electron-nucleus interaction energies, and that quark distributions change when an electron is located inside the nuclear medium.[32 33 34]

PROTON REACTIONS

Nuclear events need not only come from D or T nuclei, though these have a higher probability due to the large cross section of the strong force compared to the weak force reactions. There have been indications of the possibility of proton cold fusion reactions in various experiments.[35 36] It is suggested here that neither the *conventional* hot p-p nor the *conventional* hot p-e-p reactions could be expected to have reaction rates that explain LENR excess heat, because they are weak reactions and have clear signatures. It is expected strong force mediated lattice element x transmutations of the form p-e-x to be many orders of magnitude more probable, and that such transmutations may produce far less excess heat than the nuclear reactions and mass loss would normally indicate.

Both lattice transmutation and the radiating (p e p)* states can be expected to be preceded by formation of a briefly existing deflated hydrogen state, e.g.:

p + e <-> (p e)*

and catalyzed by the resulting (p e)* complex. The (p e)* deflated state is a neutral energy state, a degenerate quantum state that coexists with the p + e atomic or molecular state. The electron potential energy plus kinetic energy remains constant at the electron's chemical energy state reassociated with the hydrogen in whatever form. However, once, by tunneling, such a complex combines with a positive nucleus, the resulting complex, (p e p)* or (p e x)* is highly de-energized by an amount dependent upon the initial wavelength of the state that results from the tunneling and wave function collapse. This de-energizing is not energy conservative. The field energy is momentarily returned to the vacuum.

The electron catalyzed x(p,γ)y transmutation reaction occurs as follows:

p + e + x -> (p e)* + x -> (p e x)* -> y + e + γ + γ ...

or in the case of a combined weak reaction:

p + e + x -> (p e)* + x -> (p e x)* -> y + $\bar{\nu}$ + γ + γ ...

where the energy released in the form of multiple EUV or soft x-ray gammas has far less to do with the mass change from x to y than the size of the initial collapsed (p e x)* wave function. The gammas are produced from vacuum energy, as the electron goes through a process of expanding its wave length and radiating, even though the initial (p e p)* complex state is highly de-energized.

NUCLEAR ZERO POINT ENERGY

The amount and probability of zero point energy, nuclear heat, radiated in the form of photons, depends on the duration of the electron's existence in the nucleus. The existence time for the degenerate deflated (p e)* or (D e)* state is attoseconds, though its probability of existence can be high, due to a high repetition rate. This attosecond existence time greatly reduces the probability of photon emission from this state. Not so the post tunneling created de-energized composite structures, (p e p)*, (p e D)*, (D e D)*, (p e X)*, or (D e X)*, the existence of which is prolonged by the electron not having enough kinetic energy to escape. The half life of the de-energized states may also be prolonged by momentary and vacuum enabled electroweak reactions in the nucleus, some of which may in fact produce soft x-ray or EUV photons. Various of such reactions have been proposed by Giancarlo Giazzoni.

Zero point energy is available[37] to a small wavelength electron in a nucleus, via a high nucleus temperature, especially within Ni (1.02 MeV) or Al (1.70 MeV) cathodes, i.e. from a (p e Ni)* or (p e Al)* state, or in association with (p e Li)* (4.18 MeV) absorbed in cathodes.

The existence of at least a brief small wavelength (p e)* or (D e)* state, of some kind, whether as specified here or not, can not be denied. Such a configuration has a greatly increased *joint* tunneling range. Electrons exist within the nucleus with small probability even in ordinary hydrogen. Electrons exist in nuclei prior to electron capture. Such electrons have high kinetic energy, high (relativistic) mass, and small size. Electrons pass through the nucleus with very high probabilities, i.e. high repetition rates, in some molecules and it appears there is a high probability of such transits associated with partial orbitals that are created in the lattice.[38] The deflated state is proposed to be merely an elongation of the duration of the electron stay in the nucleus due to interactions of the electron and the positive quarks, especially the up quark. In classical terms, the deflated state might be viewed as consisting of roughly 10^4 orbits of an up quark per attosecond.

The reaction:

p + e < -> (p e)*

has no associated energy unless a photon emission occurs near the nucleus, but then that is another reaction entirely. The (p e)* state has an attosecond order existence. The transformation to and from the deflated (p e)* state is thus rapid and may in fact exist only in a probabilistic quantum wave form sense. It requires no stretch of imagination or credulity to accept the possibility a (p e)* state complex can tunnel as a whole, or be tunneled to, by a charged particle, with much higher probability than a bare hydrogen nucleus. Even paired electrons in superconductors have the ability to tunnel as pairs across a Josephson junction, a forbidden zone for not only a single electron, but impossible for a *pair* of electrons in any classical way due to their Coulomb repulsion when outside the superconductor.

Engineering excess heat in cold fusion is thus largely a matter of engineering high probabilities and densities of deflated states, simultaneous with high tunneling rates within the lattice.

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NUCLEAR REMEDIATION

Proton based reaction may account for a change in thorium and other decay rates in ultrasonic cavitation experiments. This was reported by Nieuwenhove,[39] who states:

"The most dramatic change in radioactive decay has, however, recently been observed by Fabio Cardone and others on the decay of thorium-228 by using ultrasonic cavitation in water.[40] In this case, the radioactive decay rate was increased by a whopping factor of 10,000."

The capture of a deflated state hydrogen (p e)* by ^{228}Th provides a surprisingly rational explanation for the results. No extra energy is required for the tunneling. The reactions are:

$$(p\ e)^* + {}^{228}Th \ \text{->}\ ({}^{229}Pa\ e)^* \ \text{->}\ {}^{229}Th + \bar{\nu}$$

The ^{229}Th has a 7900 year half-life, with a 5.52 MeV alpha decay, so it might not be noticed unless the experiment were run much longer.

It is a notable coincidence that ^{229}Pa has a 1.5 day half-life, corresponding to the observed resulting product decay rate. Also notable is that ^{229}Pa has two decay modes: electron capture, which is normally 99.8% probable, with 0.31 MeV released, and alpha decay, which is 0.2% probable, with 5.836 MeV released. However, the (^{229}Pa e)* state is highly de-energized, with the electron in continual proximity, so electron capture with no high energy radiation would be the principal result.

DEFINING SOME QUARK RELATED NOTATION

Suppose a proton is designated (u,d,u), and a neutron designated (d,u,d). This is somewhat representative of how, upon inspection, we might expect to find the quarks oriented, with the like charge quarks tending to be separated, co-located at opposing sides of the proton or neutron wavefunction. The d quark has -1/3 q charge and the u quark has +2/3 q charge, giving the proton +1 q charge and making the neutron neutral, but with an outer envelope of negative charge and inner core of positive charge. The proton tends to have an outer shell of positive charge, and an inner core with diminished charge. In an overall deuteron wavefunction, this distribution of charge tends to slightly increase the p-n bond, as of course does spin coupling. In addition there should be a kind of hadron version of the van der Waals force between the hadrons, due to location uncertainty combined with inter-hadron Coulomb colocation of quarks exposed on the surfaces of the interacting hadrons. This is a form of a Casimir force that results in some degree of bonding or attraction between any two hadrons, including two neutrons, even if for a very short half-life in the case of the di-neutron.

Now enter the momentarily nucleus bound electron, the deflated electron. A singly deflated proton p* looks like (d,u,(u e)), and is neutral, a doubly deflated proton, -p**, looks like ((u e), d, (u e)), and is negative, while a deflated neutron -n* is denoted (d,(u e),d) and is negative. The momentary (u e) couplet can be called a deflated up quark, and simply designated u*, and has -1/3 q charge. In the deflated proton, (d,u,(u e)), stress is highly reduced. The charges are of the form (-1/3, +2/3, -1/3) as opposed to the proton's (+2/3, -1/3, +2/3). The central up quark in the deflated proton is able to fully shield the repelling force between the down quark and the deflated up quark. The deflated proton thus carries much less energy into a nuclear reaction. A deflated proton thus highly de-energizes the fused nucleus, above and beyond the electron de-energization due to the suddenly increased charge of the newly fused nucleus. This energy reduction in the deflated proton also accounts for its longevity, which is estimated to be on the order of attoseconds. Note that the opposite applies to the deflated neutron, (d,(u e),d) . Its internal charges are of the form (-1/3, -1/3,-1/3) as opposed to the neutron's normal (-1/3,+2/3,-1/3). It is thus expected a deflated neutron would have a brief half-life, and cold fusion would thus be dominated by deflated proton mechanics. The situation is more complex if strange matter is involved, however, and thus the neutron can be expected to be much more involved in strange matter reactions than in fusion reactions.

WEAK REACTIONS

Here an electron neutrino is denoted ν and an electron antineutrino is denoted $\bar{\nu}$. Upon fusion, the deflated up charge u^* has the extra energy available for a weak reaction, a u^* transformation, the creation of namely:

energy + u^* -> $d + \bar{\nu}$

which might also be denoted:

energy + (u, d, u^*) -> $(d, u, d) + \bar{\nu}$

energy + p* -> n + $\bar{\nu}$

or the very unlikely:

energy + $(d, (u\ \text{e}), d)$ -> $(d, d, d) + \bar{\nu}$

energy + -n* -> Δ⁻ + $\bar{\nu}$

or the very unlikely:

energy + $((u\ \text{e}), d, (u\ \text{e}))$ -> $(d, d, d) + \bar{\nu} + \bar{\nu}$

energy + (-p**) -> $\Delta^- + \bar{\nu} + \bar{\nu}$

where the close bond between the up quark and electron provides the extra proximity-time to pull off the weak reaction with a much higher cross section than might otherwise be expected based on straight-through electron transit times through the nucleus.

The extremely unlikely reaction:

energy + -n* -> $\Delta^- + \bar{\nu}$

necessarily must take place within a deuteron or triton, and is thus of the possible overall form:

energy + -D* -> p + Δ^- + $\bar{\nu}$

energy + -T* -> D + Δ^- + $\bar{\nu}$

though there is the possibility of a slightly extended lifetime and neutral (p Δ^-) or (D Δ^-) particle forming.

The reaction:

energy + (-p**) -> Δ^- + $\bar{\nu}$ + $\bar{\nu}$

could also take place as:

energy + -D** -> n + Δ^- + $\bar{\nu}$

though there is the possibility of a briefly stable and neutral (n Δ^-) particle forming.

All the Δ^- reactions are *extremely* unlikely, essentially unobservable, and would in any case necessarily be very short lived because the Δ^- has a mass of 1232 MeV/c^2, the energy for which can only be borrowed for a very brief time. A Δ^- decays in 5.58 x 10^{-24} s into a π^- and a neutron. A π^- pion decays into a μ^- muon and muon neutrino ν_μ. The Δ^- reactions are only of possible interest within the context of cosmic ray initiated reactions, especially cosmic ray precipitated collapse of condensates which might form in hydrogen loaded nanoparticles. The fact Δ^- particles are not going to form due to high energy requirements, however, simply means that the electron or electrons are not able to cause a weak reaction, and thus are only going to play a purely catalytic role in fusion reactions initiated in the potentially Δ^- related cases described above.

The deflated up quark provides many possible reactions between deflated and ordinary combinations of protons, p + p, protons plus deuterons, p + D, and deuterons, D+D.

Among some of the more interesting deflation fusion reactions are:

$D^* + D \rightarrow (nnnp) + \bar{\nu}$

$D^* + D^* \rightarrow (nnnn) + 2\,\bar{\nu}$

$D^{**} + D \rightarrow (nnnn) + 2\,\bar{\nu}$

followed instantly by the disintegration or tunneling of the very short half life nnnn or nnnp particles into a nearby nucleus. The second tunneling might be avoided entirely by a combined 3-way wavefunction collapse on a lattice nucleus, of the form:

$D^* + X + D^* \rightarrow Y + \bar{\nu} + \bar{\nu}$

or:

$D^* + X + D^* \rightarrow Y + e + \bar{\nu}$

Reactions of the above kind would produce small apparent kinetic energy due to the reaction energy being carried off by neutrinos.

MISCELLANEOUS DEFLATION FUSION REACTIONS

Some other reactions of interest:

$p + p^* \rightarrow D + \bar{\nu}$

$p + D^* \rightarrow {}^3He + \bar{\nu}$

$p^* + D \rightarrow {}^3He + \bar{\nu}$

$D + D^* \rightarrow {}^4He + e$

$D + D^* \rightarrow {}^3He + n + e$

$D + D^* \rightarrow T + p + e$

$D^* + D^* \rightarrow {}^4He + 2\,e$

$D^* + D^*$ -> $T + p + 2e$

$D^* + D^*$ -> $^3He + n + e + \bar{\nu}$

$D^{**} + D$ -> $^4He + 2e$

$D^{**} + D$ -> $^3He + n + e + \bar{\nu}$

$D^{**} + D$ -> $T + p + 2e$

There are of course various other nuclear reactions involving tritium, lithium, and boron etc. Note that none of the highly de-energizing deflation fusion nuclear reactions would be common in a plasma because the probability of the deflated state forming with high repeatability would be nominal. The branching ratios for plasma reactions are thus very different from the deflation fusion reactions.

STRANGE EXCHANGE IN PROTON

Denote an antiparticle with an overline, so s is a -1/3 q charged strange quark, and $\bar{s}$ is a +1/3 q charged anti-strange quark.

If an $(s, \bar{s})$ virtual pair is momentarily added to a proton from the vacuum, due to vacuum fluctuations, a common event, it could be denoted:

(u, d, u) -> $(u, d, u, s, \bar{s})$

If an anti-strange quark were to nucleate the deflated state this would be denoted:

$(u, d, u, s, (\bar{s}\ e)^*)$

and the bound electron would increase the lifetime of the virtual strange quarks. By momentarily binding with the anti-strange quark, which has charge +1/3 q, the $(\bar{s}\ e)$ pair is repelled from the other strange quark s, which has a negative charge also. Post fusion this is proposed to result in:

$(u, s, u) + (d, \bar{s}) + e$

where the neutral K^0 kaon $(d, \bar{s})$, mass 497.6 MeV/c^2, goes its separate way post fusion, and the alpha formed has, in effect, a strange proton (u, s, u) replacing one of its normal protons. The (u, s, u) particle, mass 1189.3 MeV/c^2, is typically denoted uus, and called a Σ^+ particle. However, the (u, s, u) particle created via the deflation fusion process should carry much less energy than a Σ^+ particle. The ordinary Σ^+ has a mean lifetime of 8.018 x 10^{-11} s. It decays into a proton plus pion0, or neutron plus pion+. The pion0, mass 134.87 MeV/c^2, has a mean lifetime of 8.4 x 10^{-17} s and decays into 2 gammas or a gamma and electron-positron pair. The pion+, mass 139.57 MeV/c^2, has a mean lifetime of 2.6x10^{-8} s, and decays into a positive muon, μ^+, plus muon neutrino, ν_μ or a positron, e^+, plus neutrino, ν. The Σ^+ decays at a mean distance no further than 2.41 cm from its origin. As will be further described below, the (u, s, u) particle is created by deflation fusion and ends up bound in the fused nucleus. This overall vacuum exchange might be characterized as:

$$p\ (938.27\ \mathrm{MeV/c^2})\ + e \rightarrow \Sigma^+\ (1189.3\ \mathrm{MeV/c^2}) + K^0\ (497.6\ \mathrm{MeV/c^2}) + e$$

where a net energy of 748.6 MeV has been extracted from the vacuum by electron catalysis, assuming conventional energized masses for all particles. Kaons are discussed further in a separate section.

STRANGE EXCHANGE IN THE NEUTRON

Similarly for the neutron we might have, due to vacuum fluctuations:

$$(d, u, d) \rightarrow (d, u, d, s, \bar{s})$$

If an anti-strange quark $\bar{s}$ were to nucleate the deflated state this would be denoted:

$$(d, u, d, s, (\bar{s}\ \mathrm{e})^*)$$

and the bound electron would increase the lifetime of the virtual quarks. Post fusion this could result in:

$(d, u, s) + (d, \bar{s})$ + e

and the neutral K^0 kaon $(d, \bar{s})$, mass 493.7 MeV/c^2, again goes its separate way post fusion. The (d, u, s) particle is de-energized, thus likely a Λ^0, mass 1115.7 MeV/c^2, as opposed to a Σ^0, mass 1192.6 MeV/c^2. The Λ^0 has a mean lifetime of 2.631x10^{-10} s, and decays into a proton plus negative pion, π^-, or neutron plus neutral pion, π^0. The Λ^0 decays at a mean distance no further than 7.89 cm from its origin. However, as noted below, this (d, u, s) particle is created as a result of fusion and ends up bound into the fused nucleus. This overall vacuum exchange might be characterized as:

n (939.57 MeV/c^2) + e -> Λ^0 (1115.7 MeV/c^2) + K^0 (497.6 MeV/c^2) + e

where a net energy of 673.7 MeV has been extracted from the vacuum by electron catalysis, assuming conventional energized masses for all particles. Kaons are discussed further in a separate section.

It is notable that, unlike the Δ^- reactions, the strange matter reactions are a feasible means of capturing mass/energy from the vacuum via electron catalysis. The proportion of kaon production vs ordinary cold fusion depends on the probability of finding a strange quark pair within a hadron, which is a controversial number.[41] [42] [43] It may be a very rare kind of event.

It is of interest that the Λ^0 decay:

Λ^0 -> p + π^-

might account for double tracks in CR-39, and even triple tracks in CR-39 via the reaction:

Λ^0 + p -> p + p + π^-

or via other knock-ons with ^{12}C or ^{16}O. An alternate, and the original, explanation of triple tracks in CR-39, as observed by P. A. Mosier-Boss et al.[44] is the $^{12}C(n,n')3\alpha$ carbon breakup reaction:

$$n\ (9+\ MeV) + {}^{12}C \rightarrow {}^{4}He + {}^{4}He + {}^{4}He + n$$

which is further discussed below.

COMBINED STRANGE-WEAK REACTIONS

Following a strange exchange reaction, a weak reaction can occur between an up quark and a deflated electron, which remains bound to the nucleus. Again, this can be described as the sub-reaction:

$$\text{energy} + u^* \rightarrow d + \bar{\nu}$$

The Σ^+ creation process is:

$$p\ (938.27\ MeV/c^2) + e \rightarrow \Sigma^+\ (1189.3\ MeV/c^2) + K^0\ (497.6\ MeV/c^2) + e$$

where the Σ^+ is of the form (u, s, u). A weak reaction with the deflated electron can occur of the form:

$$(u, d, u^*) \rightarrow (u, d, s) + \bar{\nu}$$

$$\Sigma^{+*} \rightarrow \Sigma^0 + \bar{\nu}$$

or more likely:

$$\Sigma^{+*} \rightarrow \Lambda^0 + \bar{\nu}$$

where the close bond between the up quark and electron provides the extra proximity-time to pull off the weak reaction. The above Σ^+ creating reaction becomes:

$$p\ (938.27\ MeV/c^2) + e \rightarrow \Lambda^0\ (1115.7\ MeV/c^2) + K^0\ (497.6\ MeV/c^2) + \bar{\nu}$$

and the fusion reaction in which this is involved can become:

$$D + D + e \rightarrow T + \Lambda^0 + \bar{\nu}$$

whereby tritium is created with no initial high energy proton. However, the proton may eventually follow via the Λ^0 decay·

$$\Lambda^0 \rightarrow p + \pi^-$$

or, oddly, a neutron can follow by the alternative decay route:

$$\Lambda^0 \rightarrow n + \pi^0$$

or the Λ^0 might remain bound to the T until perturbed by sufficient energy.

A wide variety of strange-weak reactions are feasible.

ALPHA STABILITY WITH STRANGE QUARKS

Short lived baryons have almost no probability of forming directly from the deflated state because it is too brief . However, strange baryon formation in the course of fusion is much more probable. Despite the short lived nature of baryons that result from the exchange of strange quarks with down quarks, alpha particles and other nuclei with strange quark substitutions, called hypernuclei or hyperons, can be stable, although some have a low binding energy, under 20 keV.[45] Cold fusion produced stable nuclei with single lambdas include, ${}_{\Lambda}{}^{3}H$, ${}_{\Lambda}{}^{4}H$, ${}_{\Lambda}{}^{4}He$, and ${}_{\Lambda}{}^{5}He$. Stable double lambda hyperons include ${}_{\Lambda\Lambda}{}^{5}H$ and ${}_{\Lambda\Lambda}{}^{5}He$, and possibly ${}_{\Lambda\Lambda}{}^{4}H$, but ${}_{\Lambda\Lambda}{}^{4}H$ stability is controversial. The only known particle stable with a Σ^+ is ${}_{\Sigma+}{}^{4}He$, though the stability of this nucleus is controversial, and the binding energy in any case is less than 2 keV.

CHAIN REACTIONS

One important implication of the possible involvement of strange matter in cold fusion reactions is the potential for buildup of strange matter having comparatively low nuclear binding energy. The existence of such a buildup implies the potential for major excursion events which directly produce neutrons and other energetic particles, as well as muon catalyzed fusion. Heat and neutron producing excursion events, have in fact been observed,[46 47 48] including explosions,[49 50 51 52] indicating the possibility that hyperon buildup to some degree is feasible .

Hyperon based chain reactions are feasible which involve not just neutrons in the chain, but also x-ray, gamma, beta, and other particle reactions which can break the low energy stability threshold of hyperons. The only issue to be resolved is the hyperon density that can be achieved in a lattice via cold fusion or other means.

Given that the threshold for many fusion created hyperons is very low, some on the order of 20 keV, a single high energy particle or gamma can trigger more than just the required two hyperon disintegrations to sustain a chain reaction, but rather numerous hyperon disintegrations, provided the accumulated hyperon density is sufficient. Hyperon disintegration itself releases more high energy particles plus muons which catalyze fusion having high branching ratios for energetic neutrons, protons, and helium nuclei, all of which can further the hyperon chain reaction provided the hyperons are accumulated in a deuterium rich lattice.

A practical limit to hyperon density is forced by the presence of cosmic rays, especially muon containing cosmic ray showers, which clearly can trigger hyperon events if the hyperon density is sufficient. However, hyperon accumulation could occur in thin plates which could be brought together with other plates in order to achieve critical hyperon volume in order to generate excursion events, chain reactions, for the purpose of generating energy on demand.

THE KAON SCENARIOS

The K^0 particle is neutral, and thus is capable of mixing, oscillating between itself

K^0, i.e. $(d, \bar{s})$, and its own antiparticle state $K^{0\prime}$, $(\bar{d}, s)$. The frequency of the oscillation F_o being:

$$F_o = 0.5351 \pm 00.24 \times 10^{-10} \text{ s}$$

and the oscillation length[53] L_o is :

$$L_o = F_o * c = 1.6042 \text{ cm}$$

or less.

This means a target just 1.6 cm away from the source of K^0 particles, or less, might be a locus of accumulation of antimatter down quarks, or their annihilation. Interaction of an anti-K^0-short, with another hadron, feasible because the K^0 is neutral, can cause annihilation of the down quark pairs d and $\bar{d}$ present, resulting in gammas, and replacement of the proton or neutron down quark d with a strange quark s.

K^0-long, a longer half life particle, can also result, which has half life T_{long} given by:

$$T_{long} = 581\ T_{short} = 5.697\text{x}10^{-8} \text{ s}$$

and a maximum mean unobstructed path length L_{long}:

$$L_{long} = 5.697\text{x}10^{-8} \text{ s} * c = 1.71 \text{ m}$$

which might be of concern for an operator.

It is of further interest that K^0-short can decay into pion pairs, π^+ and π^-, $(u, \bar{d})$ and $(d, \bar{u})$, which have a mean lifetime of 2.6 x 10^{-8} s. The π^- decays into a negative muon, π^-, and the π^+ into a positive muon, μ^+. It is well known the π^- can cause fusion that exhibits conventional fusion branching ratios and signatures. Both the π^- and μ^+ contain antimatter quarks which are capable of creating their own energetic signature possibilities.

In addition to charged pion pairs, the K^0-long can decay into various combinations which include neutral pions π^0. The π^0 can decay into two gammas or a gamma plus an electron-anti-electron pair.

THE POSSIBILITY OF A STABLE K^0

It is well known that stable K^0 particles may exist in exotic environments, like neutron stars, or kaon stars[54] , but it is highly questionable as to whether they can exist in a metastable state bound to heavier nuclei, and whether they can be created in a laboratory environment.[55] It is a reasonable speculation that the initially negative energy environment of a cold fusion reaction might be capable of creating fully stable K^0 kaons. These would not be readily detectable in ordinary cold fusion experiments. The only signature would be an apparent alpha recoil, except the recoiling particle would not be an alpha at all, but rather a somewhat lighter hyperon. Apparent neutron events witnessed in CR-39 particle detectors could be due to neutral kaons.

EXPERIMENTAL IMPLICATIONS OF POSSIBLE STRANGE INTERACTIONS

First and foremost, it is important to ascertain whether hyperon buildup occurs or can occur in deuterium rich cold fusion lattices. This might be determined by high energy bombardment of long term cold fusion cathodes in a target area with appropriate high energy particle discrimination capabilities.

Second, tracks originating deep in CR-39 particle detectors near CF cells might in some small part be due to short half-life K^0short kaons, which decay in time T_{short}

$$T_{short} = 0.9822 \pm 0.0020 \times 10^{-10} \text{ s}$$

This gives a maximum mean unobstructed path L_{short} for the K^0short of length:

$$L_{short} = T_{short} * c = 2.94 \text{ cm}$$

or less.

This implies it might be of interest to locate a CR-39 target about 2.9 cm away from a CF cathode, or somewhat less to see if anything develops. A stack of CR-39 chips might be of interest.

A cloud chamber combined with a video camera may be of interest as a particle detector for amateurs.

Perhaps some CF signatures, the comparatively rare strange reactions, exist further away from the cell than where particle detectors are typically located. This indicates the possible utility of kaon barriers and appropriate kaon discrimination, both to protect the cell operators, and to increase the probability of close range particle detection of strange particles.

One significant problem with the hyperon chain reaction hypothesis is the lack of evidence for the radiation that should be expected in a primarily energetic photon driven chain reaction excursion event, or explosion. Though neutrons have been noted in excursion events, which would be expected from K^0 particle disintegration, an insufficient number of them have been detected to correspond with the excess heat. Also, high energy photons, such as those expected from electron-positron pair annihilation, have not been detected in sufficient quantities, though few experiments, if any, that have detected excursion events or explosions were instrumented with gamma spectrometers. However, x-rays and high energy particles, as well as mysterious radiation have been detected in numerous experiments.[56] This is an area for further investigation. If strange matter generation is key to generating some kinds of excursion events, then generating such events should now be achievable in a more reliable way, so this knowledge may improve the ability to study such events.

An obvious first step toward checking the strange matter creation hypothesis is to utilize very large CF cells. Such cells can be made of many adjacent layers of anodes and cathodes, with small electrolyte separations, so as to create a critical mass for strange matter accumulation. If the strange matter hypothesis is correct, this should increase the comparatively rare nuclear signature events, and thus permit reliable proof of nuclear effects from chemical energy inputs.

Another check for strange matter might be accomplished by taking Pd wires which have exhibited CF effects and quickly using them as filament anodes in a vacuum accelerator tube with 10 keV potential or more. This should gradually free up hydrogen and helium ions from the filament for acceleration to a target. If high energy events are detected sufficiently above background then this would be an indication further exploration for strange matter generation should be pursued.

TRACE TRITIUM AND TRIPLE TRACKS

P. A. Mosier-Boss et al. of SPAWAR discovered triple tracks in CR-39 near co-deposition cathodes. They proposed the triple tracks were from the $^{12}C(n,n')3\alpha$ three alpha producing reaction, which requires neutrons with energies greater than 9.6 MeV. This was a logical conclusion because triple tracks are commonly seen in CR-39 when high energy neutrons are present. Mosier-Boss et al. suggests the neutrons come from:

D + T --> 4He (3.5 MeV) + n (14.1 MeV)

Of additional interest is that high energy neutrons were found in association with DT cold fusion by Rusov et al.[57] Rusov et al. observed 8 (+-4) high energy neutrons per second in CR-39 using pure 50:50 DT water and 72% Pd, 25% Ag, 3% Au electrodes, and 200 V electrolysis potential. This experiment provides a solid indication of a nominal amount of DT fusion even though there is no indication that proper lattice conditions for cold fusion were established. If repeatable, that is a landmark achievement because it proves fusion from chemical conditions. Hopefully with what is known today the results can be greatly improved. However, the low counts even at 50-50 DT mix may also be an indication that the SPAWAR tracks are *not* from high energy neutrons. The SPAWAR lattice must have a negligible amount of tritium, created by cold fusion itself. The tritium branch in cold fusion is highly suppressed. Even a slight doping of the electrolyte with tritium should multiply the neutron counts in SPAWAR co-deposition style experiments by orders of magnitude - *provided* the high energy neutrons are from DT reactions.

Here the triple tracks in the CR-39 were proposed to be due to the knock-on reaction:

$$\Lambda^0 + p \rightarrow p + p + \pi^-$$

as a possible alternative to the 12C(n,n')3α SPAWAR reaction. A collision of the short half-life Λ^0 with a proton would delay it long enough and disrupt it enough to decay, producing a triple track. Other multiple track events that look like neutron events could be created from Λ^0 or K^0 knock-on reactions.

The SPAWAR data does indeed seem to suggest high energy neutrons from a DT reaction. The source of the tritium in SPAWAR experiments logically can be expected to be DD fusion, and thus of a low probability because the concentration of tritium (or possibly some form of tritium precursor) is very low. It should be no surprise that tritium can be produced in small quantities via cold fusion reactions.

The conclusion of the Mosier-Boss et al. article, that triple tracks are due to the $^{12}C(n,n')3\alpha$ reaction, implies the need for repeating exactly the same experiment using D2O + trace T2O instead of just D2O. If the flux of high energy neutrons does not increase, then the conclusion is suspect. Otherwise, this will provide some confirmation of the Mosier-Boss et al. conclusion. More importantly, if high energy neutrons can be reliably produced using the more sophisticated, successful, and controlled protocol as used by Mosier-Boss et al., this could provide a solid starting point for narrowing down the underlying physics. A tritium atom does not differ significantly from a deuterium atom with respect to the Coulomb barrier. Whatever mechanism permits deuterium to defeat the Coulomb barrier should also permit tritium to do so also. The difference should be that the tritium lattice lifetime is shorter and the tritium reaction signature unmistakable and highly repeatable.

Though the use of tritium can only be done in the US by licensed labs, and practical devices would preferably be deuterium only, trace tritium doping experiments may provide a necessary step in the progress toward practical devices. Amateur experimenters should of course avoid the use of tritium.

Because the tritium available in the SPAWAR deuterium loaded cathode must be nominal in the extreme, and likely primarily there due to DD fusion, the cross section for lattice based DT fusion has to be enormous, much larger than 100 times the DD cross section (if cross section is even a valid concept for lattice assisted fusion) to support the DT hypothesis. The tritium must be used up very quickly after forming. Lattice half-life (LHL) would be a better terminology than cross section, as applied to hydrogen loaded loaded lattices, because the term cross section presupposes a collision, kinetic interaction, hot fusion. LHL is a term which would have meaning only in the context of a specific degree of lattice loading. When highly confirmed theories of LENR are available such a term can be defined including a formula component descriptive of lattice loading conditions.

If Mosier-Boss et al. are correct in their deductions of the source of high energy neutrons, then a huge breakthrough is at hand. If contradictions are found in the DT hypothesis, or unexpected energy spectra are identified, it does not necessarily mean that increasing the DT reaction rate is not useful, and it does not mean huge benefits cannot be obtained by increasing the miniscule T concentration even by a factor of a few orders of magnitude. Trace tritium doping should be useful for analyzing and improving any CF protocol, especially those capable of producing excess heat, because detectable heat production requires a large number of reactions.

Lattice assisted DD fusion nearly eliminates the neutron forming branch, but there is no reason to believe that lattice assisted DT fusion will suppress neutron generation. In the case of DD fusion there are three branch possibilities, two of which create no neutrons. Given that a lattice assisted DD fusion nucleus is not created by energetic kinetic action, but rather by electron catalysis, it should be no surprise the branch producing the highest energy is highly favored, namely $D(D,\gamma)\alpha$, and the other feasible branches highly suppressed. There is no similar alternative branch probable for the DT or TT fusion that creates no neutrons. Trace tritium use is thus valuable for diagnosing whether excess heat is from actual fusion or from some other source.

Trace tritium doping provides a window into what is happening in the lattice, via the energy spectrum of the resulting high energy neutrons. It is not logical that DD fusion can occur in a lattice assisted manner and yet DT or even TT or Tp fusion can not. The Coulomb barrier is the same. Tritium likely provides a large tunneling target because the DT hot fusion cross section is large. Due to its mass, there is a reduced tunneling probability for T into D, but the probability of D tunneling into T is improved by the large DT cross section. If DT fusion is indeed in fact occurring in the lattice, as Mosier-Boss et al. hypothesize, it is therefore unreasonable to not expect neutron generation if T is present. However, the mechanism of fusion in the lattice is energetically different from hot fusion, and it can be expected the neutron energy to differ from hot fusion reactions. High energy neutrons as a result of DT deflation fusion can be expected to exhibit a spectrum of kinetic energies. Under that or any electron catalysis scenario, 14 MeV neutrons from DT fusion reactions can not be expected, while a significant number above 6 MeV would be expected, with a fuzzy peak.

Trace tritium doping should (a) produce highly repeatable and incontrovertible proof of nuclear reactions and (b) provide an effective means of quickly measuring reaction rates while dynamically varying experimental conditions.

If trace tritium doping is used, then lattice assisted fusion should also result in the Tp reactions: T(p,n)3He and T(p,gamma)4He. The latter reaction might be considered as unlikely as D(D,gamma)4He is conventionally considered to be due to initial kinetic energy requirements and lack of an inertial pair to distribute resulting kinetic energy. However, under the deflation fusion scenario, or some other electron catalyzed fusion scenarios, the nucleus enclosed electron provides a means of releasing radiant energy and momentum in small increments, and high initial energies are not required to trigger the reaction. The T(p,n)3He reaction requires from 1 to 5 MeV kinetic energy to pull off as hot fusion. Given that electron catalyzed fusion reactions result in highly de-energized nuclei, and the resulting radiant energy is largely from the vacuum, it may be that T(p,n)3He is feasible as a cold electron catalyzed reaction. If lattice assisted DT reactions can occur with much higher observed frequencies than expected for the reactant concentrations, as possibly indicated in SPAWAR results, then Tp reactions may also have a higher frequency than expected for the reactant concentrations. Protium from ambient humidity can be expected to contaminate D2O cells, especially long running open cells. This could account for highly variable neutron production over long run times. In a D2O experiment an initial period is required to build up trace T and another period is required to build up p. The SPAWAR CR-39 could possibly have 3He tracks resulting from T(p,n)3He or D(D,n)3He reactions, as well as neutron reaction induced tracks. All this indicates that tritium doping of even all protium based experiments may not provide adequate controls.

If lattice fusion reactions should produce high energy particles, especially third particle Bose condensate stimulation based reactions (as opposed to low energy electron catalyzed reactions), and conditions for producing many small Bose condensates exist, then it is clear that unexpected chain reactions can result. The

D(D,n)3He reaction, for example, produces two particles for each reaction. It is thus important to diagnose exactly what conditions in the lattice are producing energetic results in what proportions. It seems feasible that both 3rd particle seeded Bose condensate collapse mechanisms as well as electron catalyzed fusion mechanisms can be at work in differing proportions in differing experiments, or a given experiment at differing times. What has been missing is a means to diagnose these kinds of things. Trace tritium doping may well lead to such a diagnostic capability. It may also lead to the conclusion that the triple tracks are not from high energy neutrons.

STIMULATING TUNNELING

Deflation fusion is driven by (1) creating the deflated state with high probability, and (2) maximizing tunneling rate in the lattice. X-ray stimulation can be used to increase the latter. X-ray stimulation might be combined with radioisotope lattice doping. Impurities like B, Si, and C, are known to create interstitial locations wherein "trapped hydrogen can jump between a limited number of sites without diffusing away from the trapping atom."[58] Also noted is the fact, regarding hydrogen motion between double well potentials between two nearest neighbor tetrahedral sites, that tunneling is the dominating transport mechanism, with coherent tunneling occurring at less than 10 K, and incoherent tunneling occurring above a temperature of 10 K, and that hydrogen tunneling dynamics are a function of a nonadiabatic interaction of the hydrogen nuclei with the conduction electrons. Given the existence of such trapping sites, it must necessarily be beneficial to stimulate a high tunneling rate, using a method not involving diffusion, but rather conduction band electron stimulation. The best method of doing this seems to be to use coherent x-rays, probably from a wiggler, as that would be capable of reaching the interior of the lattice, producing a volume effect. Ordinary current stimulates tunneling, so high current densities should improve overall tunneling rate, in addition to the effect of the internal E field generated due to lattice resistance. Even if the above methods are effective at producing fusion the problem then might be too high a requirement for energy in. It may be that a resonant ultrasound vibration could be set up to stimulate tunneling without excessive diffusion. Phonons should stimulate significant conduction band - partial orbital state changes for ionically bound electrons. Stimulation throughout the lattice would also minimize the helium blocking of diffusion problem, as fusion would be triggered throughout the lattice without the need for other than the initial loading diffusion.

This then would provide a volume effect instead of a surface effect. A volume effect would make affordable reforming the lattice material periodically to purge the helium. It also would enable using reduced lattice constant material and loading at a high temperature and cooling a bit to increase orbital stressing without worries about reduced diffusion rates, because tunneling would not be diffusion driven. The problem of course is finding the right mix of all these things.

GENERAL IMPLICATIONS

The deflation fusion model indicates performance and reliability can be improved by increasing tunneling based diffusion rates, simultaneously with orbital stressing designed to increase the probability density of the deflated state.

Increased tunneling rates can be achieved within a given lattice type by imposing an E field inside the lattice. This is accomplished by decreasing the lattice conductivity and using an as large as possible current density within the lattice. Such current should thus be imposed in the lattice independently of loading current, and possibly applied in pulse mode to avoid cathode overheating.

Orbital stressing can be used to increase the probability density of the deflated state. This can be accomplished by thermal cycling, i.e. loading at high temperature and then cooling the lattice somewhat to increase tension, use of thermal gradients, use of maximum current densities with low duty cycle, increasing electron fugacity,[59] use of ultrasound, and EM stimulation including use of extreme magnetic fields and field gradients, lasers and coherent x-rays.[60] There is a glaring void of literature on the use of extreme magnetic fields, probably because this requires use of national facilities, and cold fusion is not an acceptable field for investigation.

Perhaps the most key implication is the need to reduce the lattice spacing. Pd has too large a lattice spacing, so most of its diffusion is by classical means, and all diffusion by tunneling is eliminated above 300 K. Similarly, achieving a high diffusion rate is not good enough. A lattice of Nb or some alloy with other good properties at operating temperature, but with shorter hops, should provide a significant change in tunneling rate. If Pd is used then forbidden zones in the lattice to force tunneling, or small structures which require tunneling hops to pass them, are obvious approaches. A lattice with these things might be achieved by alternating solutions or anodes during co-deposition, or by vacuum deposition and ion implantation in thin layers of alternating materials. Alternately, dense quantities of nano-particles can be imbedded to provide tunneling barriers or to channel tunneling.

A wide variety of lattice sizes and lattice structures are available for investigation and not yet fully explored.[61] [62]

Hydrogen in amorphous alloys and intermetallics have been explored for their hydrogen properties, but not cold fusion properties, including $Zr_3RhH_{3.5}$, Zr_2FeH, $(Ni_{0.5}Zr_{0.5})_{1-y}P_yH_x$, $TiFeH_x$, $Ni_{0.33}Zr_{0.067}H_x$, and including an amorphous structure, $Zr_{0.5}Cu_yNi_{0.5-y}H_1$, with an H-H separation of 1.67 Å.[63]

Thorium hydrides, ThH_2 and ThH_{15}, uranium hydride, UH_3, and fcc plutonium hydrides, PuH_x ($1.78<x<2.7$), have been explored for hydrogen properties, yet may be worth further exploring for remedial capabilities of LENR.[64]

Hydrogen properties have been investigated in a wide variety of fcc metals, bcc metals, hexagonal metals, alloys and metallic glasses.[65] Hydrogen properties in a wide variety of other metals have been investigated, including, $FeTiH_x$, LaN_5H_x, $LaNi_{5-y}Al_yH_x$ ($0<y<1.5$), $LaNi_4BH_{1.5}$, $LaCu_5H_x$, $ZrV2H_x$, HfV_2H_x, TaV_2H_x, $ZrCr_2H_x$, $ZrTi_2H_x$, $ZrMoH_x$, NbH_x, TaH_x, $ZrClH_{0.5}$, $ZrBrH_{0.5}$, $ZrNiH_x$, $TiCuH_x$, Zr_2CuH_x, $TiPdH_x$, $ZrPdH_x$, $ThNiAlH_x$, $UNiAlH_x$, $YNiAlH_x$, $ZrNiAlH_x$, $CeNiAlH_x$, $CeCuAlH_x$, $CeNiInH_x$, and $CeNiInH_x$.[66] It is especially notable that an H-H spacing of 1.48 Å is achieved in $CeNiInH_x$, which is much less than the commonly accepted distance for closest approach, 2.1 Å.

High temperature cell operation is clearly necessary to achieve practical Carnot efficiencies. High temperature hydrogen adsorption is feasible using high strength alloys of iron, tungsten, molybdenum, and other metals which are incapable of significant hydrogen adsorption at room temperature. Hot operating alloys can be designed to maximize bond strength, annealing ability, operating temperature range, and hydrogen loading as well as helium de-loading characteristics in a controlled temperature range cycling profile. Special lattices and environments can also be designed to maximize heavy transmutations and accomplish nuclear remediation.

The nuclear reactions discussed here, though of academic interest, are in the great minority of those feasible.[67] Investigation of much wider range of materials is clearly advisable, and the referenced reports provide some leads along those lines.

None of the specific individual approaches indicated by the deflation fusion model are especially unique. Most have been implemented successfully over the last 20 years to one degree or another. However, this indicates a strength to the assumptions in the model, especially the presence of an initially near ground state catalytic electron in the process. The implications of the model are surprisingly consistent with a wide number of observations. What the theory brings to the table is a narrowed focus on initiating hydrogen *tunneling* in the lattice, *combined* with orbital stressing, especially partial orbital stressing, designed to increase the probability of the deflated state.

There are clearly extensive possibilities for the exploration of LENR. The best way to do so is through use of an interdisciplinary team, backed by extensive laboratory and computing facilities. Expertise in electrochemistry, nanotechnology, materials science, particle physics, supercomputer simulation, and a wide variety of engineering fields is required. The best lattices and operating conditions are not likely to be found by Edisonian search, but through a combined computational-experimental approach which is team directed. This is not likely to happen unless better evidence for and control of LENR is obtained. It is hoped the deflation fusion concepts will assist in some way in reaching those goals.

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