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AN EXPLANATION OF COLD FUSION AND COLD FUSION BY-PRODUCTS, BASED ON LATTICE INDUCED NUCLEAR CHEMISTRY

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In this paper, first we re-examine the assumptions associated with applying the fundamental "scientific paradigm"[1] of hot fusion to the problem of cold fusion and then explain how much of the cold fusion controversy can be reconciled once an alternative paradigm, based on solid state physics, is adopted. The new world-view that results from this different perspective is the basis of our "Lattice Induced Nuclear Chemistry" (LINC) theory[2] of cold fusion. We conclude the paper by summarizing some of the more important results of LINC. These include our predictions (prior to the experimental work by Bush et al[3]) that 1) it is to be expected that the primary cold fusion by-products in the electrolytic experiments involving Pd and D probably are heat and low-energy ^{4}He, 2) the ^{4}He should remain largely untrapped within the bulk electrode and be found primarily in the surface region and outgases, and 3) there is a need to satisfy a critical loading condition (of $x \sim 1$ in PdD_x) in the electrolytic experiments.

The conventional paradigm of nuclear fusion is that two, clearly identifiable deuterium nuclei "collide" at a specific location and give off energy as a result of the ensuing decrement in mass. Three critical assumptions of this paradigm are: 1) the participants of the reaction are "particles" (of nuclear dimension), 2) the particles are readily identifiable, and 3) the reaction occurs at a specific (readily identifiable) location of nuclear size.

Preparata[4], in particular, has emphasized that as a result of these three assumptions most "normal" physicists consider nuclear processes in cold fusion to be impossible because of a single fundamental idea: "how is it possible to 'penetrate' the Coulomb barrier." He has also suggested that a second important idea must be reconciled: "how is it possible to evade Asymptotic Freedom," where Asymptotic Freedom refers to the notion that on the length scale associated with nuclear interactions, individual "particles" <u>must</u> <u>behave</u> as if they are free particles.

There is a third issue that "normal" physicists raise as an objection to cold fusion being the result of nuclear reactions: "the lack of discernible high-energy particle nuclear ash" that Jones[5] has recently suggested is important. The basis of this issue is that "normal" fusion reactions result when nuclear particles collide at a specific location. Then, if cold fusion is the result of "normal" fusion reactions, energetic by-products not only must be produced but released from the solid because the energy from nuclear reactions is so large that none of the known, "normal" electrostatic processes that occur within a solid is capable of "trapping" the energy inside the solid without violating energy or momentum conservation.

In our theory, we reconcile this final issue in a manner consistent with the way we reconcile all the issues: we simply replace the three initial assumptions of the fusion paradigm with a set of new assumptions. The new assumptions, in fact, arguably are more suitable at low temperature because they are based on the single, established "paradigm" of physics, "solid state physics", and the remaining laws of quantum mechanics.

As we explain elsewhere in this Proceedings[6], the reason that solid state physics allows us to reconcile the three "problems" of cold fusion is that through the solid state physics paradigm, to minimize the energy of the system, a solid may alter the corpuscular nature of the potentially reacting "particles" in important ways. As a consequence, 1) the locations of the participating "particles" need not be clearly defined, 2) each of the resulting nuclear reactions may occur at all periodically equivalent locations, and 3) only a small fraction of a particle need be found and reaction take place at an individual location. In other words, "just because a deuteron looks like a particle, and it acts like a particle in one place, it does not have to look like or act like a particle somewhere else; just because the energy from nuclear fusion is released entirely in one place in one case, fusion energy does not have to be released all in one place in a different case; where the energy is released, and whether or not the deuterons behave like particles are both dictated by the known laws of solid state physics, quantum mechanics, and the requirement that the energy of the system be minimized."

As we have shown[2,7], consistent with the experimental conditions of cold fusion, this alternative paradigm provides a means of altering the spatial distribution and physical make-up of nucleons in a manner that completely invalidates the underlying premises associated with conventional Gamow theory, the very concept of a huge Coulombic barrier (that must be penetrated for fusion to occur) and the expectation that "conventional" fusion products are to be expected. Also, because the new world-view begins with the idealization of the solid state physics paradigm, the prerequisite boundary condition of the resulting description is that the system is periodic in the low temperature limit and system energy be minimized. Thus, the wave function of each reactive deuteron must solve the Schroedinger equation of a bound particle, interacting with a periodic, electrostatic potential. As a consequence, the wave function does not asymptotically approach the wave function of a free particle at short length scales, and asymptotic freedom "can be evaded" simply because it does not apply.

The starting point for understanding LINC is the idealization in which a macroscopically infinitesimal number of deuterons attempt to bond to a fully loaded, stoichiometric, periodic PdD host. A very important aspect of this problem is that it applies to PdD, where it is known that the loading is dominated by the bonding effects associated with hybridization of s-electrons from the injected deuterons with 5s and 4d states provided by the Pd. As a consequence, near x=1 in PdD_x, as has been shown in several ab initio electronic structure calculations[8,9], only a very small (~ 0.1 e), predominantly isotropically distributed (and s-like) electronic charge occupies the region in the vicinity where the deuteron cores bind to the solid. (For this reason, the D are only weakly bound to [and undergo large zero-point-motion fluctuations about] their equilibrium positions.)

In order to minimize energy with respect to further injection of D atoms beyond the value x=1, four important effects then may come into play. 1) Because system energy must be minimized with respect to changes in the electronic structure, in the limit in which only a macroscopically infinitesimal number (~10^{-7} e/unit cell) of electrons are added (as a consequence of injecting additional deuterium atoms), the additional electronic charge will be distributed among the unoccupied 5s-like states immediately above the Fermi level, which are associated with electrons which are found predominantly (i.e., more than 90 percent of the time) in regions away from the locations where the D-nuclei preferentially bind in the stoichiometric ($x=1$) compound. 2) Because only an infinitesimal number of D atoms are added, again to minimize the electrostatic energy of the system, each additional D-nucleus "attempts" to bind to an octahedral site, where D-nuclei do bind in the limit that $x=1$. 3) As a consequence of the first two factors, each added D-nucleus behaves as if it is a D^+ ion that interacts with a time-independent, periodic potential over time scales that are short with respect to times associated with the disruptions of periodic order that result from interactions with phonons, finite-size effects, etc. 4) Then, because the potential is periodic, the deuterons, which effectively are ions, may occupy energy band states, <u>and</u>, provided the number of deuterons that are injected is sufficiently small (< ~ 10^{-4} x N_L, where N_L is the total number of unit cells[7]), it becomes energetically favorable, as a means of minimizing strain energy, for them to do so.

The key points are that the additional deuterons will occupy energy band states near the limit $x=1$ as a means of minimizing energy, and they effectively behave like ions as a consequence of the <u>known</u> electronic structure of PdD. Because each ion occupies an energy band state, only a very small fraction ($1/N_L$) of each ion is located in each unit cell. Because each of these band state deuterons behaves like an ion, each of them is indistinguishable from the others. Then, they all must share a common, many-body wave function. The result of these effects is that small fractions of a deuteron may interact, without the prerequisite Coulombic tunnelling requirement[7]. Reaction occurs as a consequence of the implicit algebraic properities of the many-body wave function provided the zero-point-motion broadening of the deuteron wave function is sufficiently large.

Because only a small fraction of each excess deuteron is present at any site, only a small fraction of each reaction (and reaction energy), on the average, occurs at each site. Energy release occurs only through processes which preserve the quasi-equilibrium conditions which give rise to the occupation of the initial state many-body, ion band state wave function. This requirement leads to a selection rule that final state by-products in the primary reaction channels be formed from integer numbers of proton-neutron pairs. (^{3}H and ^{3}He, protons and neutrons are explicitly excluded.) Also, high energy radiation is forbidden, and the dominant low temperature processes approximately preserve periodic order. As a consequence, at low temperature, in agreement with the experimental findings of Bush et al[3], LINC predicts that the dominant interactions involve the production of ^{4}He through occupation of ionic ^{4}He energy band states with subsequent energy release through coupling to phonons or coherent motion (in which the lattice moves as a whole), accompanied by the expulsion of "untrapped", low-energy ^{4}He (from ionic energy band states) into the surface and outgasing regions. Release of high energy alpha particles at isolated sites is allowed and is promoted by sudden disruption of crystalline order (which may occur, for example, when the electrolytic overpotential is suddenly reduced).

[1] T. S. Kuhn, *The Structure of Scientific Revolutions, Vol II*, 10, (Univ. of Chicago Press, Chicago, 1962).

[2] S. R. Chubb and T. A. Chubb, in *Anomalous Nuclear Effects in Deuterium/Solid Systems*, AIP Conference Proceedings 228, 691, (Amer. Inst. Phys. (New York), 1991).

[3] B. F. Bush, J. J. Lagowski, M. Miles and G. S. Ostrom, *J. Electroanal. Chem.* **304**, 271, (1991). Also, talk presented by M. Miles during this meeting.

[4] G. A. Preparata, *Fusion Technology*, **20**, 82, (1991).

[5] S. E. Jones, private communication (1991).

[6] T. A. Chubb and S. R. Chubb, "Cold Fusion and a Non-Corpuscular View of Matter," in this Proceedings.

[7] T. A. Chubb and S. R. Chubb , *Fusion Technology*, **20**, 93, (1991).

[8] A. C. Switendick, in *Hydrogen in Metals I*, 101, (Springer, Berlin, 1978).

[9] D. A. Papaconstantopoulos, B. M. Klein, J. S. Faulkner, and L. L. Boyer, *Phys. Rev. B* **18**, 2784 (1978).

EDITORIAL NOTE TO THE PAPER "AN EXPLANATION OF COLD FUSION..." BY S.R. CHUBB AND T.A. CHUBB

In spite of strong objections of the Referees, we publish this paper, for we wish that all attempts of explanation of a new phenomenon be brought to the attention of the readership, provided they are not trivially wrong or pointless.

The Referees' objection focus on the low credibility of an approach that tries to avoid the difficulties of the existence of a Coulomb barrier between deuterons, by assuming that deuterium is in fact spread out on a large region.

In quantum physics it is the probability amplitude, not the matter distribution, that is spread out. Thus the view presented is in fact in disagreement with quantum mechanics.