Physical Description of Cold Fusion

Evan RAGLAND
6640 Ahekolo Circle
Diamondhead, MS 39525
UNITED STATES of AMERICA

ABSTRACT

Cold nuclear fusion of deuterium in an electrolysis cell with palladium electrodes is described as a comprehensive sequence of physical phenomena.

1. Electrolysis generates many more cations than are necessary to sustain ionization in the cell. The excess cations are adsorbed on the cathode surface where they create an electrical charge Q_o of "overvoltage" E_o.
2. A small fraction (0.01 to 0.1%) of the adsorbed cations, which are thousands of times smaller than typical electrolysis cations and driven by meV adsorption kinetics, penetrate several hundred lattice layers into the cathode metal. These nuclei absorb into the metal until its capacity C (n_t) saturates.
3. Because palladium metal has the property of nucleonic conductance, or "viviance", absorbed nuclei propagate throughout the metal until the internal charge Q_i reaches equilibrium with the adsorbed charge Q_o.
4. For a properly configured cathode, the density of absorbed deuterium nuclei can reach a critical level where the Coulomb force of nuclei crowds those near the cathode center to nuclear fusion.
5. The low kinetic energy of crowded fusion nuclei results in the principal nuclear reaction: [$D^2 + D^2 > H^1 + T^3 + E$]. The [n + He^3] reaction product is essentially repressed. Due to the short range of the energetic proton and triton in the metal, only trace product gases escape the cathode. Hence, excess heat is the predominant external evidence of the nuclear reaction.

These physical phenomena are examined in detailed theoretical arguments. It is concluded that the phenomena of cold fusion can and does occur, and that the physical explanations given in this paper reconcile the overwhelming experimental evidence supporting cold fusion.

FRONTIERS OF COLD FUSION

"THROUGHOUT the history of science new discoveries and new ideas have always caused scientific disputes, have led to polemical publications criticizing the new ideas, and such criticism has often been helpful in their development; . . . . . This violent reaction . . . . can only be understood when one realizes that the foundations of physics have started moving; and that this motion has caused the feeling that the ground would be cut from science." Werner Heisenberg, Physics and Philosophy, Harper & Brothers, 1958.

1. Introduction

Since 23 March 1989, when Stanley Pons and Martin Fleischmann startled the scientific world with the announcement of sustained nuclear fusion in an electrolysis cell using heavy water electrolyte and palladium electrodes, controversy worthy of Heisenberg's philosophy has raged. Proponents of this new discovery have determinedly advanced experimental research and in many instances have achieved significant and remarkably encouraging results. Opponents have consistently discounted these results as errors in experimental technique and interpretation. This is peripheral controversy. More significant are the substantive criticisms that there is; 1) no theoretical basis for the reaction, 2) no experimental repeatability, 3) no neutron product from branching reactions, and 4) no neutron or other radiation from secondary reactions.

These negative arguments are helpful in that they identify reasonable scientific concerns and thus define basic questions that must be answered positively. This paper addresses these questions. In response to: 1) it proposes that the Coulomb force of absorbed deuterons crowds those near the center of the palladium cathode to nuclear fusion; 2) it suggests from the mechanics of 1) a sufficiently comprehensive understanding will evolve to explain already reported experimental results and to guide future experiments; 3) it argues that the kinetic energy of the nuclear reaction is so low and the Coulomb repulsion of the protons so high that one or the other deuteron decomposes into a neutron and a proton before the nuclei are close enough to fuse, the neutron suffering no repulsion and continuing on to fusion with the surviving deuteron while the energy of the reaction is carried away by the proton; and 4) it maintains that the low kinetic energy of nuclei in the neighborhood of fusion essentially represses secondary product nuclear reactions and that the only subsequent reaction is the decay of tritons to helium 3 nuclei.

Simply put, cold fusion occurs when deuterons produced by electrolysis absorb into the palladium cathode where accumulation ultimately crowds those near the center of the cathode to [d-d] nuclear fusion. The primary product of the reaction is excess heat; a secondary product is ß radiation from the decay of tritium. Other possible reactions are suppressed by the fusion environment. More explicit explanations follow. Of particular interest may be the theoretical construct for crowding fusion, the postulated mechanics of the nucleonic conduction property of metals (viviance), and the logical extension of the Mayer/Jensen Shell Model of the nucleus to develop an Alternate Model to the generally accepted Standard Model.

2. Theoretical Construct

A space enclosed by a source of kinetic deuterons accumulates deuterons until in equilibrium with the source. Theoretically, a threshold can be reached where deuterons crowd to fusion near the center of the space. The construct envisions a hypothetical fusion cell in which a sustained envelope of deuteron plasma concentrates deuterons inward toward fusion. Fusion diameter, charge volume (C), viviance, and charge time are formulated for the threshold of fusion.

The special case of a spherical source of diameter D_o simplifies description of the physical mechanics of the cell. A constant charge;

$$Q_o = N_o \text{ deuterons, } (= N_o \times e^+ \text{ in esu}), \quad (1)$$

is assumed to be uniformly distributed about a spherical surface of diameter D_o as shown in Figure 1(a). Deuterons emanate from the source until the plasma charge Q_i within the sphere is in equilibrium with the source charge Q_o. Since the charge at the center of the sphere must be zero, the internal charge along any diameter ranges, from q_o to zero to q_o, as shown in Figure 1(b).

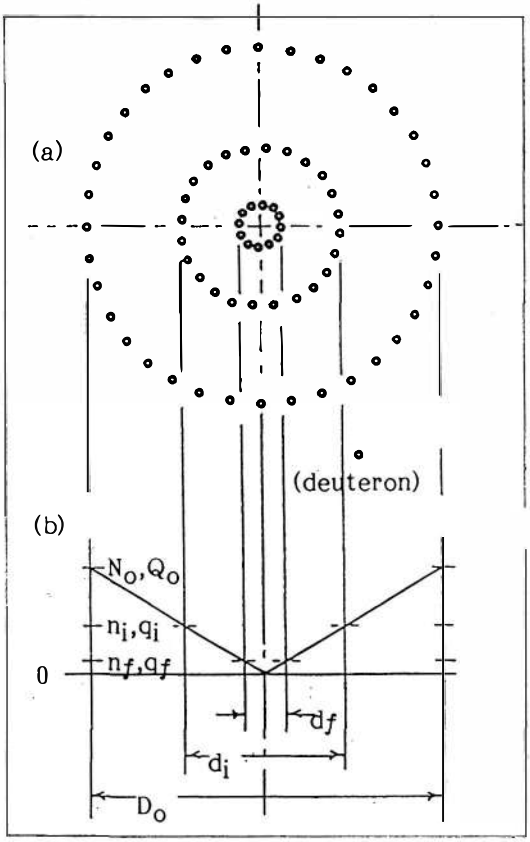

Figure 1. Theoretical construct.

The effective charge at any concentric spherical boundary ($d_i < D_0$) within the plasma is;

$$q_i = d_i Q_o / D_o, \quad (2)$$

and the number of charge elements n_i in that charge is;

$$n_i = d_i N_o / D_o. \quad (3)$$

The charge elements of cross sectional area A_e are uniformly distributed about the spherical area A_i; where,

$$A_e = \pi (d_e)^2/4, \quad \text{and} \quad (4)$$

$$A_i = \pi (d_i)^2. \quad (5)$$

When the product of the number of deuterons n_i and the cross sectional area of the deuteron A_e equals or exceeds the spherical surface area A_i fusion may occur; i.e. when,

$$n_i \geq 4(d_i/d_e)^2. \quad (6)$$

From (3) and (5) the diameter d_f and the number n_f of fusion elements in terms of the diameter of the deuteron d_e are,

$$d_f = (d_e)^2 N_o/4D_o, \tag{7}$$

$$n_f = 4d_f^2/d_e^2. \tag{8}$$

From the logic of these arguments and equations the theoretical conclusion is drawn that; Fusion of deuterons will occur about the center of a spherical space bounded by a constant deuteron charge supply source Q_o when that source exceeds the internal charge element storage capacity Q_i of the space. This is consistent with Coulomb's Law and simply stated is; Crowding Fusion is, f(constant charge source), f(finite charge space) when,

$$Q_o(D_o)^2 \geq q_f(d_f)^2, \tag{9}$$

where q_f is the fusion charge and d_f is the diameter of fusion.

Fusion will occur when,

$$4d_f^2/d_e^2 = 1. \tag{10}$$

From (12) the critical diameter of fusion for n_f deuterons is,

(FUSION DIAMETER) $$d_f = (n_f d_e^2)^{\frac{1}{2}}/2. \tag{11}$$

The distance separating deuterons λ_i has a rate of change with respect to diameter d_i that is proportional to λ. Thus, the number of deuterons n_d across the diameter D_o is,

$$n_d = (\lambda_o - d_f)/d_e + (d_f/d_e), \tag{12}$$

where the distance between deuterons at source Q_o is λ_o; and the distance between deuterons at d_f (λ_f) is d_e.

Since d_f and d_e are (10^{-5} x λ_o) or smaller,

$$n_d \approx \lambda_o/d_e. \tag{13}$$

The approximate number of deuterons n_t to charge the volume to fusion is then,

(CAPACITY) $$n_t \approx \pi(\lambda_o/d_e)^3/6. \tag{14}$$

Q_o supplies a constant deuteron charging current called j for convenience. The transfer function relating it to the sustaining current i_o of the ionizer; i.e. the liveliness or viviance of diffusion of the deuteron in the charge medium, is designated by the symbol μ where,

(VIVIANCE) $$\mu = j/i_o. \tag{15}$$

It is convenient to measure j in amperes since the ionization of one deuteron D^+ in the source removes one electron e from the source. Then the charge time to fusion t_f is,

(CHARGE TIME) $$t_f \sim n_t/j. \quad (16)$$

This analysis can be extended to any charge medium of any shape that is within a closed charge source. Of particular interest at this time are palladium (Pd) cathodes of cold nuclear fusion electrolysis cells.

3. Viviance

Accumulated absorptivity of energy and matter crowds deuterons to cold fusion. This requires, 1) a sustained source of kinetic deuterons, 2) a field for inward drift of absorbed deuterons, and 3) the cathode bulk property of nucleonic conductance or viviance. The adsorptive kinetics of charge Q_0 enveloping the cathode surface of the cold fusion cell; 1) sustain a source of kinetic deuterons, a small fraction of which penetrate the cathode, and 2) develop back voltage E_0 which establishes a positive absorptive field gradient. The reversible formation and dissociation of palladium deuterides 3) provides the mechanics of viviance.

Adsorption kinetics at the cathode surface create an ionosphere of randomly moving low meV deuterons. Most capture electrons and escape the electrolyte as deuterium gas or scatter as they collide with the cathode surface. A few with direction of travel either parallel (~ 1° of arc) to a crystal plane or coincident (~ 0.3° arc) with a crystal channel penetrate the cathode. Repulsion of the nuclei of the crystal tends to confine these to the open space of the plane or channel. They may travel several hundred lattice layers into the crystal before being absorbed. The size of the deuteron relative to other molecules, atoms, and ions present in cell electrolysis, also contributes to the depth of penetration.

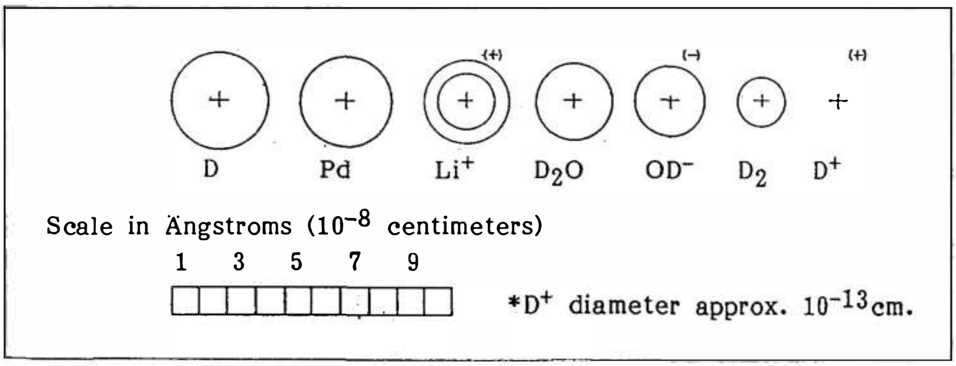

Figure 2. Size of molecules, atoms, and ions in cell electrolysis.

The systematic conditions existing at any moment in a single metal crystal with at least one surface exposed to a deuterium ionosphere include ions, atoms and molecules of deuterium and deuterides of the metal. The electrostatic charge of an individual single crystal is equal to the totality of charge of the ions extant in the crystal at that moment. These conditions maintained; 1) this charge increases until it reaches equilibrium with the surface charge of the crystal and 2) deuterides ultimately form at all vacancies and at the boundaries of the crystal where incompleteness of crystal structure abound. In summary the single metal crystal might be characterized as a temporary electrical storage cell.

This systematic description of a single metal crystal is inadequate to describe the characteristics of the bulk metal. The composition of metal is grains of polycrystalline structure. This polycrystalline structure is schematically illustrated in Figure 3.

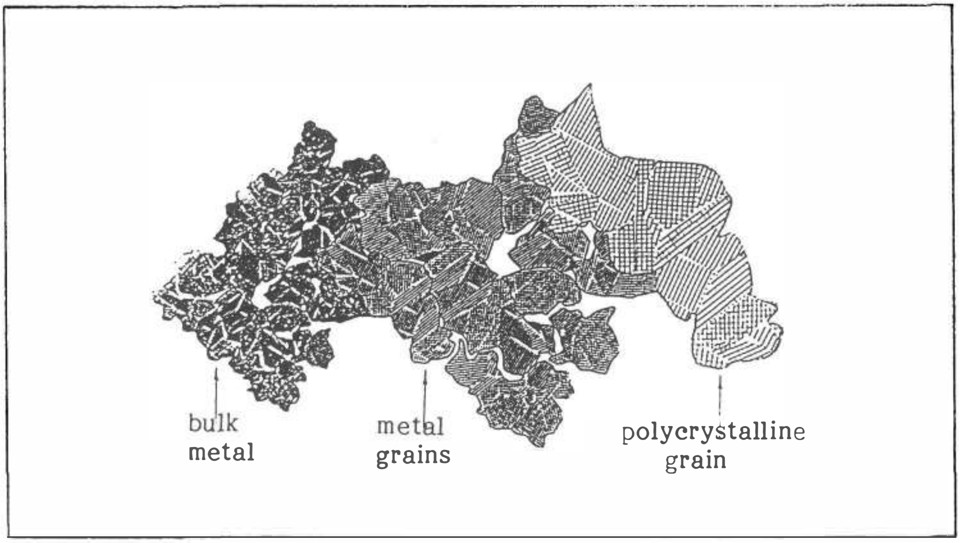

Figure 3. Polycrystalline/grain/bulk metal structure.

The typical grain structure of metals results from uneven solidification. Individual grains are seldom perfect single crystals. Generally numerous crystals of random orientation commence growth as solidification begins. A polycrystalline mass forms as these grow into one another. Disorder and structural incompleteness abound along crystalline boundaries within the polycrystalline mass. Deuterides of the metal may form along these boundaries, grain boundaries, and at other sites of structural incompleteness or irregularity. Further, there is adequate open space within the arrangement of atoms in palladium to accommodate deuterons and/or deuterium as interstitial impurities.

Deuterium exhibits almost metallic properties in alloy like deuterides, is partly positive in character and can act as a connecting bridge between metal atoms. Interstitial deuterons may expand the crystal structure and can change the phase of the structure. In palladium the deuterides may take several distinct phases $Pd_{2n}D_n$ where n is not necessarily an integer.

$Pd_{2n}D_n$ may be explained as a co-ordination compound; i.e., atoms that are united by co-ordinate bonds or valences in accordance with Werner's Co-ordination Theory. The mechanism of these bonds relies on the metallic like properties, small size, and positive charge of the deuteron to attract electrons from neutral palladium atoms which have unshared electrons. The maximum number for the deuteron as the central ion in the co-ordinate compound is 2. Thus the deuteride Pd_2D forms as,

Pd·D·Pd.

The deuteride Pd_4D_2 forms about the deuterium molecule as,

Pd. .Pd
. D·D .
Pd˙ ˙Pd.

Formation of Pd_2D and Pd_4D_2 is enhanced by the square planar complexes formed by covalent complexes of bivalent palladium which configure the four corners of the square coplanar with the central ion. All palladium compounds are easily decomposed and these deuterides are particularly unstable. Dissociation of palladium deuterides is reversible.

When thermal activation or kinetic disturbance causes a deuteride to dissociate deuteron(s) leave behind a negative lattice site and become conducting particle(s) free to drift in the electric field of the lattice. The typical drift path is erratic, being continually interrupted by collisions which the deuteron makes with the atoms of the lattice, with other deuterons, atoms and molecules of deuterium, etc. However, the average of deuteron drifts in the presence of cathode overvoltage E_o is inward toward the center of the cathode. The vacated negative lattice site(s) becomes available as temporary store for other deuteron(s) spent of kinetic energy. This transfer function is the conductive mechanism of viviance; the nucleon is the conducting particle, the fixed lattice sites the conducting medium, and the cumulative absorbed kinetic energy the work.

The argument is advanced that natural thermal dissociation of deuterides at polycrystalline and grain boundaries and at other crystal lattice imperfections is accelerated by kinetic encounter with newly arriving deuterons. This releases secondary deuterons to further propagate within the crystal. These nucleons tend to be repelled from crystals of higher positive charge toward neighbor crystals or grains of lesser charge and to drift along boundaries in the general direction of the field gradient of E_o. Thus nucleon mobility, the interstitial capacity of the individual crystal to absorb nucleons, and the pathways of metallic boundaries to the interior of the metal are the operative mechanics of viviance.

Systematic absorption continues until the internal charge Q_i is in equilibrium with the source charge Q_o. Equilibrium may be reached before deuterons crowd to fusion depending on individual characteristics of palladium cathode specimens.

4. Alternate Model

The fusion of nuclei is more easily visualized from the Alternate Model (a logical extension of the Mayer/Jensen Shell Model) than from the generally accepted Standard Model of the atomic nucleus.

The logic of the Standard Model constructs nucleons, protons (p) and neutrons (n), from sub nucleon particles. Simply explained, each nucleon is constructed of three quarks (electric charges) bound together by three gluons (carriers of the nuclear strong force). According to this model the atomic nucleus is a cluster or clump of nucleons bound together by the nuclear strong force of gluons.

The logic of the Alternate Model constructs the neutron as the complement of the hydrogen (protium) atom; i.e., an electron captured inside a proton. The neutron's resultant internal electric field is the nuclear strong force. According to this model the atomic nucleus is a concentricity of individual nucleon fields, each confined to a distinct shell location by wave length and angular and spin momenta. The structure conforms to the Pauli exclusion principle, the principles of quantum mechanics, and with the exception of the protium nucleus is bound together by the neutron(s) internal field(s).

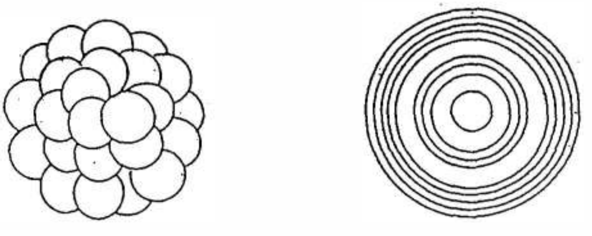
Standard Model	Alternate Model

Figure 4. Models of the atomic nucleus.

5. Crowding Nuclear Fusion

Cold fusion in an electrolysis cell is a deuteron to deuteron [d-d] reaction caused by Coulomb crowding. The products of the three possible d-d nuclear reactions are: 1) [p + ^{3}H], 2) [n + ^{3}He], and 3) [^{4}He + gamma ray]. High energy deuteron fusion experiments have shown that reactions 1) and 2) occur in about even proportions. Reaction 3) is not expected as it requires even higher energies to occur. It is generally assumed that reactions 1) and 2) should always produce a 1:1 branching ratio. Reported neutron observations in cold fusion experiments are 10^{-9} to 10^{-6} of the expected product. Hence, it is concluded the absence of neutrons proves there is no nuclear reaction. This conclusion is specious. Reaction 2) does not occur in cold fusion, therefore no neutrons should be observed.

The interaction of the strong forces of the nuclei causes the nuclei to fuse. Fusion occurs when nuclei are crowded to within one nuclear diameter of one another even though they possess no kinetic energy. The [d-d] reaction in a crowded environment ($\lambda \sim 10^{-12}$ cm.) is illustrated (in accordance with the Alternate Model) in Figure 5. Two deuterons D^+, thermally activated, move toward collision at time t_o. Their kinetic energies are small fractions of an electron volt. At time t_{-n+1} the proton *(clear) and the neutron (hatched) of each deuteron are concentric* about a common center. At some later time t_{-2} they remain centered, but the neutrons internal fields distort in reaction to the Coulomb repulsion of the protons. Later at time t_{-1} one proton overcomes the neutron field and breaks free of the common center. At time t_o the overlap of the neutron strong forces begin to draw the neutrons toward a common center and the Coulomb repulsion of the two protons begins to move them apart. By time t_{+1} the triton has formed and begun to "settle in" and both it and the proton move apart with added kinetic energy from the fusion reaction.

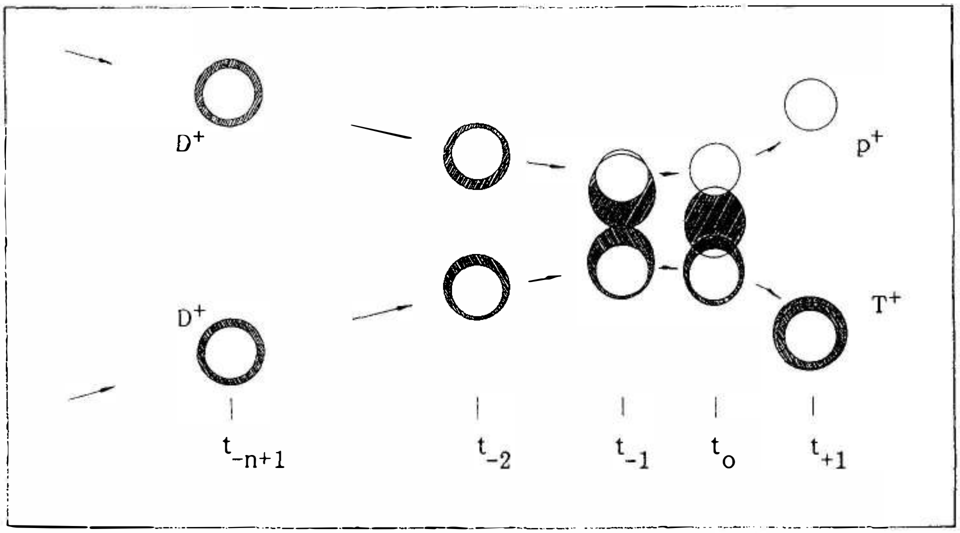

Figure 5. Model illustrating deuteron to deuteron fusion.

The Alternate Model is used for ease of illustration. The same results can be demonstrated using the Standard Model but the conceptualism lends to ambiguity. The argument is that the inertial velocity possible for thermally excited deuterons in the micro dimensions of crowding precludes the collision of the proton components.

6. Conclusion

It is concluded that the phenomena of cold fusion can and does occur. The reaction is a bulk effect. The physical mechanics are simple; almost primitive. Accumulation of absorbed kinetic deuterons can cause Coulomb crowding to reach [d-d] nuclear fusion reaction levels near the center of high viviance electrolysis cell cathodes. Most transitional metals (Ti to Ni, Zr to Pd, and Hf to Pt) exhibit viviance. The VIIIA metals Pd, Pt, and Ni in its ß phase are unusually viviant. Because of the low kinetic energy of the fusing nucleons only the [d-d] > [p-t] reaction occurs. As a result the primary energy product is heat and the primary radiation product is tritium decay.

The cold fusion cell is inherently small in size and power output as a result of the micro dimensions of the reaction. Large power sources will require batteries of cells. Any disadvantage from this should be largely offset by flexibility of sizing and independence of location. The lack of neutron radiation has positive environmental impact when compared to hot fusion reactions.

Naturally solidified metals are marginally suitable for fusion cell experiments. Cathode metals with controlled and predictable characteristics would accelerate experimental progress.

Cold fusion is one of the great discoveries of natural phenomena. With it comes the potential to open new physical realms beyond just the generation of energy. Much scientific credit is due Pons and Fleischmann for this discovery.

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