A COLD FUSION THEORY

A COLD FUSION THEORY

David D. Moon
Minneapolis, Minnesota
October, 1993

Prepared by
William M. Johnson
Richfield, Minnesota

Perhaps no scientific marvel of the twentieth century is a better example than cold fusion of the visionary philosophy written by Eugene F. Mallove in Fire From Ice: "...the eternal challenge of science [is] not to follow where the worn path may lead, but to go instead where there is no path, and leave a trail."

This effort in cold fusion theory is dedicated to the visionary scientists working in the field - not least of whom are Drs. Martin Fleischmann and Stanley Pons - and without whom this theory would not have been possible.

Giuliano Preparata talked about the agony of having a blank piece of paper in front of him and facing the challenge of the unknown.

Carol White
21st Century Science and Technology,
Winter 1992, page 62.

Contents

We seem to be looking at some sort of cooperative, collective, or coherent phenomenon.

Michael McKubre
Stanford Research Institute

I. Introduction

A model of deuteron behavior in deuterium loaded palladium or titanium is presented. A single description of the deuteron dynamics, that of a collective, coherent oscillating train of deuteron waves, is proposed to account for a number of interactions between deuterons and the metal's nuclei or electron cloud. These interactions are then proposed to explain most of the variety of nuclear signatures being measured, including energetic charged particles, tritium, helium-4, low-level neutrons, gamma radiation and isotopic shifts of elements.

The theory makes a prediction that metals with isotopes having large thermal-neutron absorption cross sections will react better with deuterons in the lattice (for example, cadmium alloyed with palladium or titanium). Ideas for test cells are offered.

An attempt is also made to relate this theory of coherently oscillating deuterons to the phenomenon of sonoluminescence and acoustically driven fusion. In addition, a prediction is made of fission of heavy metals in some cold fusion experiments.

One thing we can say for sure: This is not an ordinary nuclear reaction.

Hideo Ikegami,
National Institute for Fusion Science,
Nagoya, Japan.

II. The Theory

A. Charged Particles at the Naval Research Laboratory

Energetic charged particles were measured at the Naval Research Laboratory when thin (1 micron) films of titanium were bombarded with 350 eV deuterium ions. [1] Researchers there predicted that spectral peaks in the detector (which was 4.99 MeV in "sample 1") could be accounted for by tritons formed at an initial kinetic energy between 5.38 MeV and 6.0 MeV. [1a]

These charged particle emissions are proposed to be the result of a nuclear interaction between the deuteron and the titanium-48 nucleus within active volumes inside the lattice.[1] The deuteron serves as a neutron donor to the metal nucleus:

$$\mathbf{d + Ti^{48} \rightarrow Ti^{49}(0.12MeV) + p(5.80MeV)}$$

The energy distribution between Ti^{49} and the rejected proton is estimated according to classical momenta calculations. The 5.8 MeV proton will immediately react with

---

[1]Titanium-48 is the most likely of the titanium isotopes to react. It has the highest thermal neutron absorption cross section, 8 barns, which may correlate with this reaction, and its abundance is 74%.

a trailing deuteron (part of the invading train of deuteron waves discussed below). Analysis of the NRL data suggests that most of the p-d fusions will result in a ~5.8 MeV triton (median energy), although some ~ 5.8 MeV He^3 particles can form. (See Chapter V.) The proposed reactions are:

$$p(\sim 5.8\text{MeV}) + d \rightarrow t(\sim 5.8\text{MeV}) + \beta^+(\sim 5.47\text{MeV})$$

$$p(\sim 5.8\text{MeV}) + d \rightarrow He^3(\sim 5.8\text{MeV}) + \gamma(5.49\text{MeV})$$

The triton can form at a range of 5.45 MeV (when positron is ejected straight forward) to 6.15 MeV (positron ejected straight backward). (The same energy range occurs for He^3).

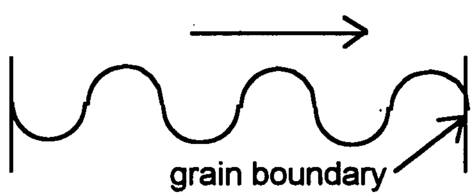
B. Coherent Deuterons

To account for a reasonable reaction rate between deuterium and titanium nuclei in producing the 5.8 MeV proton at NRL it will be necessary to take a collective approach to the deuteron-titanium interaction. On the subject of quantum field theory, Dr. Giuliano Preparata states that "on the theory of quantum field coherence one resolves the apparent particle-wave duality by treating an assemblage of particles according to field theory, which emphasizes their dynamic interaction. Then one treats the collection as one physical object."[2a] Commenting on Preparata's theory, Dr. Francesco Scaramuzzi states, "there is a connection between cold fusion and superconductivity - since they are both substantially collective phenomena. You can measure properties of a mass of material which are explainable only in terms of quantum mechanics, but on the macro scale. You don't have to look at single nuclei. If Preparata is correct, then cold fusion also demonstrates a collective phenomenon." [2b]

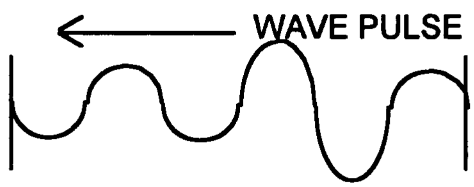
...substantiality - the existence of "objects " - exists only in the macrocosm, while the reality of such objects is the collective wave behavior of the "particles" of which they are composed.

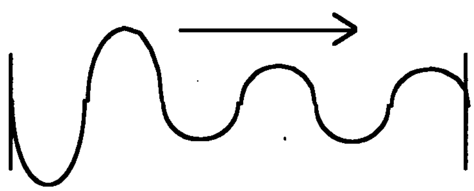
Giuliano Preparata

Deuterons inside an active volume of the Ti (or Pd) lattice must behave collectively and coherently as one physical object. This model will describe the dynamic interaction of an organized assembly of deuteron waves, oscillating collectively and coherently within an active volume. This active volume is pictured as being defined by grain boundaries, which serve as reflective barriers (the mirrors in optical lasers) for an oscillating and finally resonating, train of deuteron waves:



Reflection of the train of waves will create a kind of constructive interference:





The growing deuteron wave pulse will intensify, provided the collective deuteron energy was "pumped up", until it tunnels close enough to the metal nucleus to enact the reaction,

$$\mathbf{d + Ti^{48} \rightarrow Ti^{49} + p, \text{ if the grain boundary atom is } Ti^{48}}$$

For the d + Ti^{48} reaction, the normal threshold energy required for d to enter the neutron - absorption cross - sectional area, assuming this close approach is necessary, is 1.98 MeV (See Chapter V Section A.). The idea is to focus the collective wave behavior - through the resonating wave pulse - at the titanium nucleus.

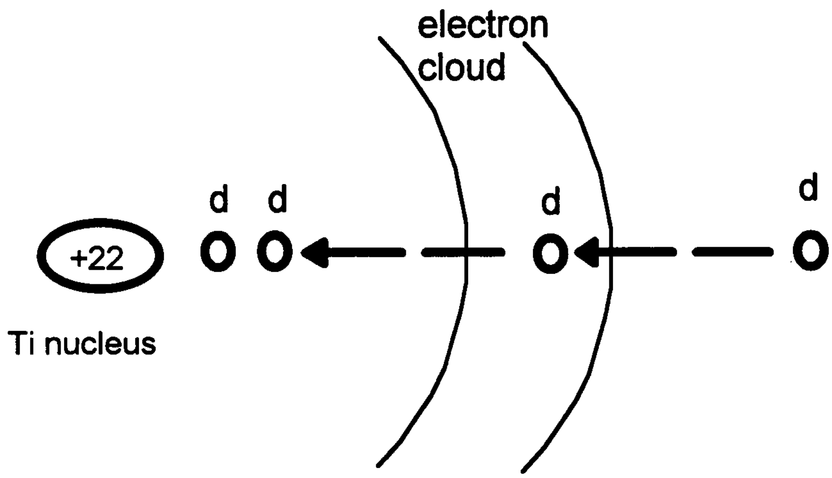
In a hypothetical example, let an "active length" within an active volume equal ~ 10 μm(~10^5 Ti).Let the average energy of the resonating deuterons equal 25 eV, so the velocity equals $4.9\text{x}10^6$ cm/sec. Therefore, the frequency of the oscillating (resonating) wave pulse is:

$$\mathbf{f = \left(\frac{4.9x10^{6}\,cm\,/\,sec}{2x10^{-3}\,cm} \right) = 2.45x10^{9}\ /\,sec}$$

The collective deuteron energy for D / Ti = 1 (that is, 10^5 D) is about 25 eV x 10^5 = 2.5 MeV, which exceeds the threshold of 1.98 MeV.

In this example, the frequency of oscillation of 2.45 x 10^9 /sec is of interest since it is in the microwave range. The experiments at NRL used an electron cyclotron resonance (ECR) microwave (2.45 GHz) plasma source to produce the deuterium - ion beam. The microwave intensity at the titanium sample during bombardment was ~ 10 mW / cm^2 . Further, researchers at NRL state that "the high particle production rate observed in these experiments was obtained using an ECR microwave ion source, but when a Kaufman ion source was used instead, high particle production rates were not observed."[1b]

To review, energetic tritons (or He^3) can form when the collective energy of the deuteron wave pulse, in the oscillating train of deuteron waves, is enough to enter the volume of the metal atom, near the neutron - absorption cross - sectional area:



The leading deuterons of the invading train of deuteron waves approach the n - absorption cross section of the metal nucleus to bring about the reactions:

$$d + Ti^{48} \rightarrow Ti^{49}(0.12MeV) + p(5.8MeV),$$

$$p(\sim 5.8MeV) + d \rightarrow t(\sim 5.8MeV) + \beta^{+}(5.47MeV),$$

$$p(\sim 5.8MeV) + d \rightarrow He^{3}(\sim 5.8MeV) + \gamma(5.49MeV).$$

The positron formed in these reactions will likely annihilate inside the metal atom's electron cloud. The resulting two or three gamma photons, still within the electron cloud, may accelerate electrons and thereby reduce the gamma intensity.

C. Some Other Charged - Particle Experiments

Palladium has exhibited charged - particle emissions in deuterium - ion bombardment. For example, both E. Cecil[3a] and A. Takahashi[2c] reported energy peaks at about 5 MeV.

Conceivably, palladium isotopes could react, such as Pd^{108}:

$$\mathbf{d + Pd^{108} \rightarrow Pd^{109}(0.04MeV) + p(3.89MeV),}$$

followed by

$$\mathbf{p(\sim 3.89MeV) + d \rightarrow t(\sim 3.89MeV) + \beta^{+}(5.47MeV)}$$

or, perhaps Pd^{105}:

$$\mathbf{d + Pd^{105} \rightarrow Pd^{106}(0.04MeV) + p(7.28MeV),}$$

followed by

$$\mathbf{p(\sim 7.28\ MeV) + d \rightarrow t(\sim 7.28\ MeV) + \beta^{+}(5.47MeV)}$$

However, at a neutron - absorption cross section of 12 barns, for instance, Pd^{108} requires a threshold energy of 3.38 MeV for the collective deuterons to bring about the d + Pd^{108} reaction.[2] These reactions might only occur at high input power or voltage.

---

[2]In these reactions, the assumption is being made that the deuteron must enter the cross - sectional area required for thermal - neutron absorption by the metal nucleus. Such a correlation has yet to be shown by experiment. Nevertheless, the general proposal for these reactions is expected to be unaffected, because a resonant - neutron absorption by the metal nuclei, where this neutron is carried by the incoming deuteron, could be also valid, and closer to the actual description than a thermal - neutron absorption.

Instead, silver impurities in palladium might have been the source of ~5 MeV charged particles seen by Drs. Cecil and Takahashi. For the silver isotopes:

	n-absorption cross-section	threshold energy for $d + Ag \rightarrow p$(MeV)
Ag^{107}	35 barns	2.05 MeV
Ag^{109}	89 barns	1.27 MeV

Their reactions with the invading deuteron wave pulse are:

$$d + Ag^{107} \rightarrow Ag^{108}(0.05MeV) + p(5.00MeV),,$$

$$p(\sim 5.0MeV) + d \rightarrow t(\sim 5.0MeV) + \underset{\text{median energy}}{\beta^{+}(5.47MeV)},$$

$$d + Ag^{109} \rightarrow Ag^{110}(0.04MeV) + p(4.56MeV),$$

$$p(\sim 4.56MeV) + d \rightarrow t(\sim 4.56MeV) + \underset{\text{median energy}}{\beta^{+}(5.47MeV)},$$

A by-product of these reactions is an isotopic shift to cadmium:

$$Ag^{108} \rightarrow Cd^{108} + \beta^{-}, \text{half life 2.4 minutes}$$

$$Ag^{110} \rightarrow Cd^{110} + \beta^{-}, \text{half life 24 seconds}$$

Platinum impurities in palladium could also be a source of charged particles:

$$d + Pt^{195} \rightarrow Pt^{196}(0.03MeV) + p(5.67MeV),$$

$$p(\sim 5.67MeV) + d \rightarrow t(\sim 5.67MeV) + \beta^{+}(5.47MeV),$$

where threshold energy for d + Pt^{195} = 3.69 MeV

Other experiments producing MeV-level charged particles from palladium include gas-discharge experiments (Y. Kucherov[2d]), and electrochemically charged palladium foil (Taniguchi[1a]). Also, Dr. Eiichi Yamaguchi showed charged - particle emissions from gas loaded palladium foil.[2e]

Dr. Yamaguchi's unique electrode design of a palladium foil sandwiched on one side by a gold layer and on the other side by manganese oxide, might have actually contributed to the number of charged particles in some experiments. It was hypothesized that high deuterium concentrations develop within "accumulation layers" at the Pd/Au and Pd/$MnO_{(x)}$ interfaces. The expected consequence would be a greater coherency of deuteron oscillations with the input of proper electrical voltage. Therefore, the following reactions likely occur at the interfaces when Au or Mn serve as grain boundaries for the oscillating train of deuterons in a Yamaguchi cell:

(1.)

$$d + Mn^{55} \rightarrow Mn^{56}(0.10MeV) + p(4.95MeV),$$

$$p(4.95MeV) + d \rightarrow t(\sim 4.95MeV) + \beta^{+}(5.47MeV),$$

median energy

$$p(4.95MeV) + d \rightarrow He^{3}(\sim 4.95MeV) + \gamma(5.49MeV),$$

median energy

For Mn^{55}, n-absorption = 13.3 barns and the threshold energy for d + Mn^{55} is 1.74 MeV.

At the manganese oxide boundary, transmutations to iron would result:

$$Mn^{56} \rightarrow Fe^{56} + \beta^{-}, \text{ half life } = 2.6 \text{ hours.}$$

(2.)

$$d + Au^{197} \rightarrow Au^{198}(\sim 0.03MeV) + p(4.24MeV),$$

$$p(4.24MeV) + d \rightarrow t(\sim \underset{\text{median energy}}{4.24MeV}) + \beta^{+}(5.47MeV),$$

$$p(4.24MeV) + d \rightarrow He^{3}(\sim \underset{\text{median energy}}{4.24MeV}) + \gamma(5.49MeV),$$

For Au^{197}, n-absorption = 98.8 barns and the threshold energy for d + Au^{197} is 2.03 MeV.

With a half life of 2.7 days, the Au^{198} formed will undergo beta decay to Hg^{198}. However, with a thermal-neutron absorption cross section equal to 26,000 barns, Au^{198} invites additional charged-particle production in Dr. Yamaguchi's gold coated palladium foil:

$$d + Au^{198} \rightarrow Au^{199}(0.03MeV) + p(5.31MeV),$$

$$p(\sim 5.3MeV) + d \rightarrow t(med.5.3MeV), \text{ or } He^{3}(med.5.3MeV)$$

The threshold energy for d + Au^{198} is only 0.12 MeV!
Mercury should be found at the gold boundary:

$$Au^{199} \rightarrow Hg^{199} + \beta^{-}(\text{half life} = 3.15 \text{ days}).$$

In Dr. Yamaguchi's electrode construction using Au /Pd /$MnO_{(x)}$, however, energetic tritons or He^3 particles that form at the gold layer will not be detected since ~ 5 MeV charged particles could not pass through 1 mm of Pd foil to reach the detector, which was placed 6 cm in front of the $MnO_{(x)}$ surface. In a presentation given at the 3rd international conference on cold fusion in Nagoya, October 1992, Dr. Yamaguchi and his associate, Dr. Takashi Nishioka showed charged particle data that gave energy peaks in the range of 4.5 MeV - 6.0 MeV.[4a,5] An energy shift using an intervening 7 μm foil indicated these particles were probably He^3 or alpha particles. Peaks which appeared at about 4.5, 4.7, 5.0 and 5.2 MeV could be accounted for by charged particles formed when the invading deuterons reacted with Ag (as Pd impurity), and with Mn at the Pd /$MnO_{(x)}$ interface, as reviewed on pages 9 - 10.

Isotope	Median Energy of He3 or T (MeV)	Energy Range Formed At (MeV)
Ag^{107}	5.0	~4.65 - 5.35
Ag^{109}	4.56	~ 4.2 - 4.9
Mn^{55}	4.95	~ 4.6 - 5.3

An unexplained peak appeared at about 5.8 MeV. Deuteron reaction with Pt^{195}, producing He^3 and tritons at an initial kinetic energy of ~ 5.3 MeV to ~ 6.0 MeV, would be a candidate to account for this peak. But the threshold energy for d + Pt^{195} is 3.69 MeV, greater than for d + Pd^{108}[3] Instead, one is led to look for another impurity in manganese that reacts strongly with deuterons in the lattice, to account for the 5.8 MeV peak. Or, tiny amounts of some impurity added to palladium during preparation of the sample - which must be allowed for in nearly every operation - could be the culprit causing mysterious energy peaks, provided the impurity had a strong reaction with the oscillating trains of deuterons to produce a few fast tritons or He^3 nuclei.

Sherlock Holmes would have loved cold fusion.

---

[3]Of course, the possibility is that the reaction d + Pt^{195} → Pt^{196} + p(5.7 MeV) does not correlate with the thermal - neutron absorption cross section, but is a resonant effect instead. If so, Pt^{195} might react better with deuterons than do the Pd isotopes, which then could explain the presence of particular, unexpected energy peaks for charged particles and the absence of others.

Referring again to the charged - particle spectrum at NTT Labs, it appears that two sets of isolated energy points were recorded. One set consisted of deposits at 6.6 - 7.0 MeV (average ~ 6.8 MeV) and another at ~ 8.5 MeV.[5]

Cadmium should, at 20,000 barns for neutron absorption, react strongly with deuterons in the Pd lattice:

$$\mathbf{d + Cd^{113} \rightarrow Cd^{114}(0.06MeV) + p(6.76MeV),}$$

followed by

$$\mathbf{p(\sim 6.76MeV) + d \rightarrow t(\sim 6.76MeV)} \text{ or } \mathbf{He^3(\sim 6.76MeV)}$$

median energies

These charged particles can form at a range of 6.4 to 7.1 MeV.

In the NRL experiments(page 4) the proposal was that titanium - 48 produced charged particles at an initial kinetic energy of 5.45 to 6.15 MeV (median 5.8 MeV). The "titanium solution" to the 5.8 MeV mystery, and the "cadmium solution" to the 6.8 MeV mystery would be a nice way to end a story on charged particles.

But, of course, Arthur Conan Doyle couldn't be consulted.

(3.) Energetic alpha particles

In the Yamaguchi electrode, the other isolated set of energy deposits, at ~ 8.5 MeV, might have come from secondary t - d fusions after the d + Mn^{55} reactions manufactured a few 4.95 MeV tritons:

$$\mathbf{t(\leq 4.95MeV) + d \rightarrow He^4(\leq 4.95 + 3.5 \leq 8.45MeV) + n(14.1MeV).}$$

median

Finally, it is noted that Dr. A. Takahashi found that, "There was also a strange 8 MeV helium peak measured during deuteron implantation of titanium foils."[2c]

When a 5.8 MeV triton is produced in deuterated titanium, as in the NRL experiments (G. Chambers et al.), it has a certain chance also of undergoing a secondary reaction in t-d fusion.[4]

$$t(\sim 5.8\ \mathrm{MeV}) + d \rightarrow He^4(5.8 + 3.5 = 9.3\ \mathrm{MeV}) + n(14.1\ \mathrm{MeV}),$$

A ~9.3 MeV He^4 passing out through a few microns of metal thickness could deposit an energy of ~ 8 MeV in the charged particle detector (see table of data for He^4 deposits on page 41)

D. Manufacture Of Tritium.

Generous and repeatable quantities of tritium continue to be manufactured in a variety of cold fusion cells. However, if the reactions forming energetic tritons accounted for levels of accumulated tritium, an associated neutron emission of 10^{-5} to 10^{-4} n / T would occur from secondary t-d fusions:

$$t(x\mathrm{MeV}) + d \rightarrow He^4(x + 3.5\mathrm{MeV}) + n(14\mathrm{MeV})$$

Because this minimal neutron flux is not measured when tritium appears, it is a general opinion that when accumulated tritium is created, it is created at very low kinetic energy.

---

[4]It is not known by this author if any ~8 MeV to ~9 MeV particles were measured at NRL.

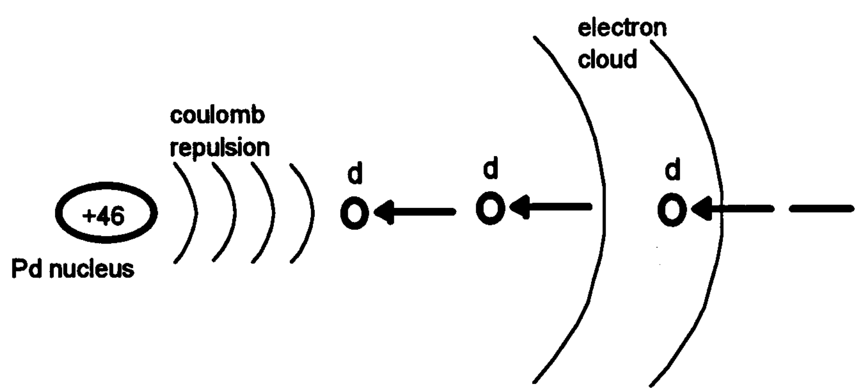
The following reactions are proposed to account for low-energy tritium with accompanying low-level neutrons:

$$d + e^{-} \xrightarrow{\text{electron capture}^{5}} n_2(\text{dineutron})^{6}$$

$$2d + n_2 \rightarrow 2T(Q \approx 10.27\,\text{MeV})$$

The oscillating deuteron field enters volume of metal atom:

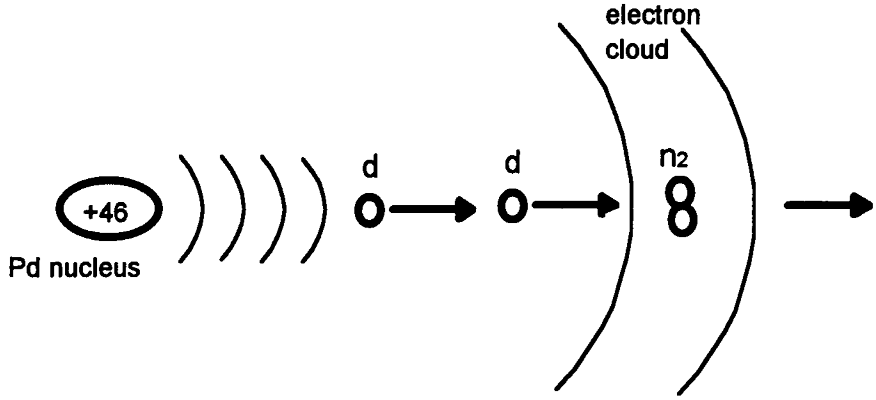
(a.) Leading deuterons of deuteron wave pulse reach inside of metal atom's volume; a trailing deuteron reaches only into electron cloud.



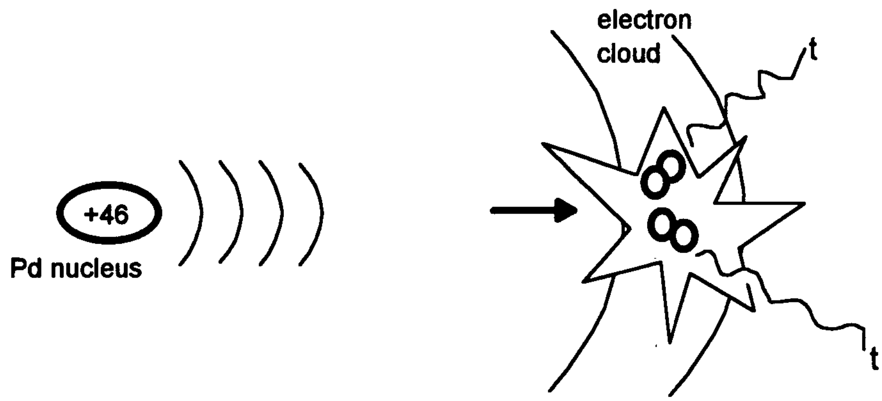
---

[5]Denotes: inside metal's electron cloud.
[6]Ref. to n_2 by J. Yang, Dept. of Physics, Hunan Normal University, China.[4a]

(b.) Deuteron inside electron cloud captures electron, converting to dineutron.



(c.) Rebounding deuterons meet inside electron cloud: $2d + n_2 \rightarrow 2t + 10.27$ MeV, or $d + n_2 \rightarrow t + n + 4.0$ MeV.



Since tritium forms at very low energy, it must be proposed that most of the reactions, $2d + n_2 \rightarrow 2t$, occur inside the electron cloud *and* that the electron cloud carries away most of the energy release. It is also necessary that the large majority of reactions are "double reactions", yielding two tritium, because a single fusion ($d + n_2 \rightarrow t + n$) will produce a low-energy neutron which would in turn produce isotopic shifts as well as gamma radiation by neutron capture on palladium. Such secondary effects are not generally observed when tritium appears.

The energy release of 10.27 MeV for this double reaction was estimated by assigning 2.23 MeV consumed in the n_2-breakup (the same as the p-n binding energy). This may only be good for an approximation:

$2d + 2n \rightarrow 2t$	+12.50 MeV
$n_2 \rightarrow 2n$	- 2.23 MeV
$2d + n_2 \rightarrow 2t$	+10.27 MeV

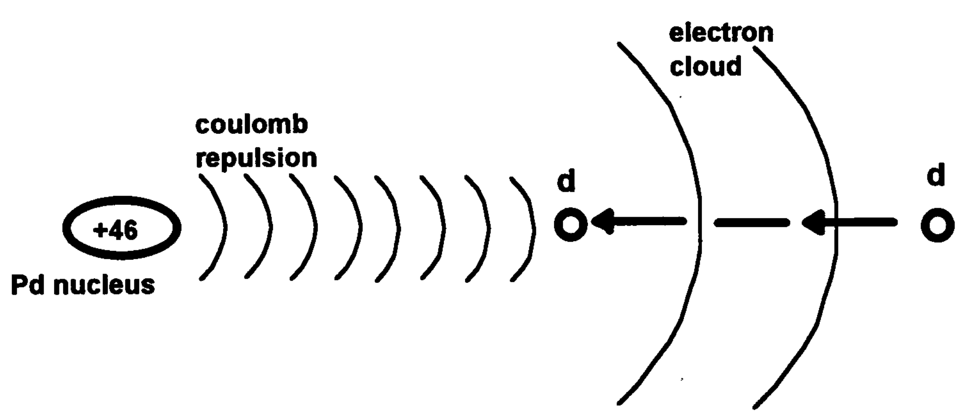
In case the reaction is $d + n_2 \rightarrow t + n$ outside the electron cloud, energy distribution of the 4.0 MeV should be according to normal momenta distribution, that is, $d + n_2 \rightarrow t$ (1.0 MeV) + n (3.0 MeV). Evidently this occurs infrequently since n/T is typically $\sim 10^{-8}$.

E. Helium-4/Excess Heat.

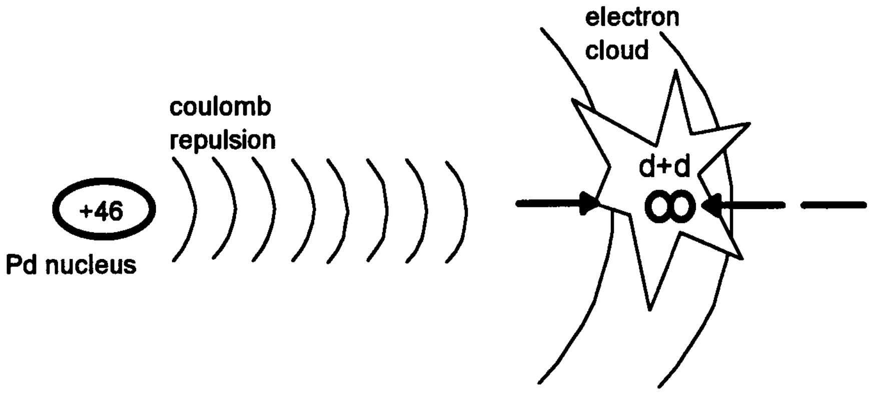
Reports of finding helium-4 are becoming more common and the correlation with excess heat may possibly yet be confirmed. At the Nagoya Conference in October, 1992, researchers E. Yamaguchi, M. Miles and N. Oyama reported some expected ratios of heat/helium-4 in their experiments.[2f]

The mechanism producing helium-4 in this theory, which is offered as the primary source of excess heat, is given as:

(a.) Leading deuteron reaches just inside electron cloud.



(b.) Rebounding d meets trailing d inside cloud: d + d → He^4 + 23.8 MeV (carried by e^- field).



Dr. Eugene Mallove writes of Dr. G. Preparata's theories, "Their paradigm was a 'plasma' of charged particles within a lattice that were oscillating collectively around equilibrium positions...The general direction he reported was the plasma of electrons inside the solid lattice carrying energy away from the deuterium fusion reactions, and in doing so suppressing the two usual outcomes of d-d fusion - the helium-3 and tritium branches."[3b]

> The lack of electromagnetic radiation and 14 MeV neutrons indicates that the resulting nuclear energy is not communicated to the individual nuclear products. In other words, the energy appears to couple to the lattice rather than to the product atoms.
>
> Edmund Storms, Los Alamos National Laboratory

The d - d fusions inside the metal's electron cloud are likely to generate a few energetic electrons. It recently has been published that, "Direct conversion of cold fusion energy to electrical power in cold fusion batteries has already been reported."[4b] Again, Dr. Mallove writes of Dr. Peter Hagelstein's theory, "that the energy [23.85 MeV] might unload itself directly into the excitation of electrons... and if the fusion is actually managing to couple to the current going through the palladium cathode, then the cold fusion process might become in some sense an amplifier of electrical power." [3c]

Maser - like emissions?

Reactions given in this theory, including d + d → He^4 (Q=23.85 MeV), occur because the deuteron energy is able to act collectively and coherently in the metal lattice. The Q released is largely distributed over ~10^9 smaller electromagnetic - field vibrations in the lattice, or ~24 MeV/10^9 ≈ 0.024 eV per atom, which is about the value for a thermal atom. Thus, ~10^9 lattice vibrations have been "pumped up" (about doubled) by a single d - d fusion.

> ... matter is not made up of individual particles interacting like billiard balls, but is organized by the coherent action of electromagnetic fields.
>
> Martin Fleischmann and Giuliano Preparata

Energy from d - d and d - n_2 fusions inside the metal's electron shell could also be distributed through the coherent deuteron field which is oscillating at a microwave frequency. The frequency of the train of deuterons would become pumped up. From a single d - d fusion inside the electron cloud, the intensity of the microwave oscillations of the deuterons is increased by an estimated, ~24 MeV/10^6 deuterons ≈24 eV. Coherent microwave frequencies intensified in this way can result in a burst of microwave photons emitted from the cathode.

Just such an event was reported to have caused a nontrivial burn on the finger of an unidentified researcher - performing a Pons-Fleischmann electrolysis - when a burst of microwave energy from his cold fusion cell resonated with the atoms in his gold ring.[6]

F. Summary of the Theory.

A spectrum of reactions in PdD or TiD ranges from production of energetic charged particles at high input, high resonance, to excess heat, helium and isotope transmutations at low input. A number of variables affect cell performance. However, this model will remain elementary and propose that:

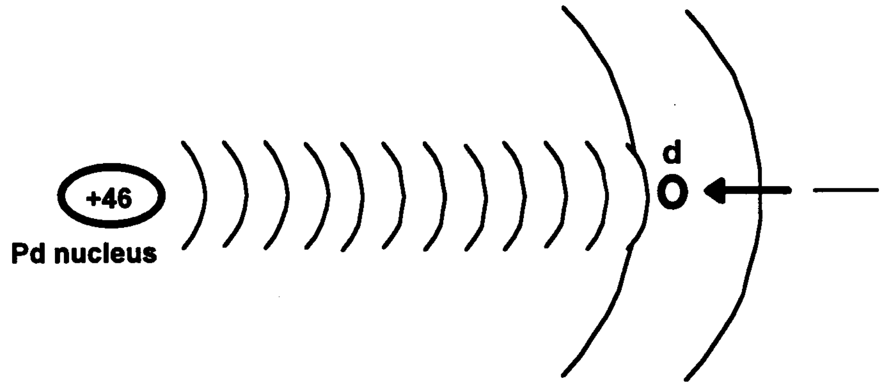
(1.) At high voltage, or when deuteron oscillations are highly resonating, the collective deuteron wave is able to produce charged particles by the reactions d + Pd(or Ti)→p(MeV), followed by p(MeV)+d→t(MeV) or He^3(MeV). This reaction rate is highest when input power is largest, or when there is a high degree of coherence (assuming sufficient energy level of deuterons) as was the situation at the Naval Research Laboratory when the oscillating deuterons resonated with the microwave flux striking the titanium sample.

(2.) At a somewhat lower input power there is the manufacture of low-energy tritium: $2d + n_2 \xrightarrow{e^- \text{cloud}} 2T + 10.27\text{MeV}$ (spread through the lattice), with a few reactions of $d + n_2 \rightarrow t(1.0\text{MeV}) + n(3.0\text{MeV})$. The rate of tritium production is related to the applied voltage; this was determined by Professor John Bockris and his students at Texas A and M University.[2g]

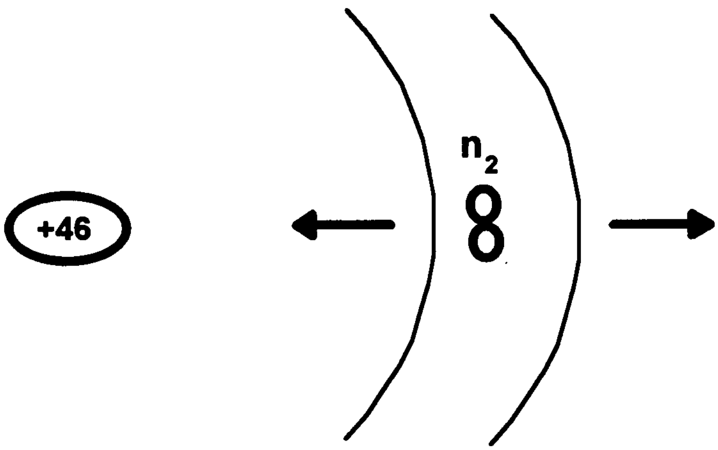
(3.) At still lower input power there is d + d→He^4 inside the metal's electron cloud. This is postulated to be the primary heat forming reaction in all cold fusion experiments using heavy water or heavy hydrogen. One implication of this reaction mechanism is that more heating should occur during *lower* input power. This relation might have been seen in at least two experiments. In Dr. A. Takahashi's famous alternating high-low electrolysis, the output/input ratio was greater during the low current cycle.[7] Experiments similar to Takahashi's were performed by Dr. Antonella de Ninno, et al., at ENEA in Frascati, Italy. She reported "Excess power maximum was 1,000 percent in the low power mode and 100 percent at high power."[2h]

(4.) Finally, at even lower local input power, free dineutrons can form. Reactions between the dineutrons and metal nuclei can account for certain neutron spectra, isotopic shifts of palladium, and super asymmetric fissions of palladium and platinum (discussed in Chapter IV).

(a.) Leading deuteron reaches only into electron cloud.



(b.) Deuteron captures e- to form n_2.



The low - energy dineutron may react with a palladium nucleus to form another isotope plus a neutron:

Reaction	Q(reaction)
$Pd^{102}(n_2,n)Pd^{103}$	5.38 MeV
$Pd^{104}(n_2,n)Pd^{105}$	4.86 MeV
$Pd^{105}(n_2,n)Pd^{106}$	7.31 MeV
$Pd^{106}(n_2,n)Pd^{107}$	4.30 MeV
$Pd^{108}(n_2,n)Pd^{109}$	3.92 MeV
$Pd^{110}(n_2,n)Pd^{111}$	3.49 MeV

These neutron - forming reactions could explain portions of some neutron spectra that have been reported. For example, Dr. A. Takahashi had a neutron spectrum that included a peak in the region of 3 - 7 MeV.[7] Also, at the Nagoya conference, a Chinese team reported a neutron emission between 2.5 and 7.0 MeV.[4a]

Another possible reaction is the capture of the dineutron by Pd. Example:

$$\mathbf{Pd^{110} + n_2 \rightarrow Pd^{112} (Q = 11.84MeV)}$$

Then Pd-112 decays:

$$\mathbf{Pd^{112} \xrightarrow{-\beta^-(21h)} Ag^{112} \xrightarrow{-\beta^-(3h)} Cd^{112}}$$

Transmutation to cadmium, but Cd-114 only, was discovered in palladium foils using acoustic energy (Micro-Fusion, R. Stringham)[6]. Therefore:

$$\mathbf{Cd^{112} + n_2 \rightarrow Cd^{114} (Q = 13.36MeV)}$$

Other n_2 - capture reactions might account for isotopic shifts to silver, found in some spent Pd samples:

$$\mathbf{Pd^{105} + n_2 + n_2 \rightarrow Pd^{109} \xrightarrow{-\beta^-(13.5h)} Ag^{109}}$$

G. A Slice of π : Testing the Theory.

The cold fusion theory presented has speculated that the deuteron - metal reaction, d + $M^A \rightarrow M^{A+1}$ +p(MeV), which is responsible for energetic charged particles according to p(MeV) + d → t(MeV) + β^+, or He^3 (MeV) +γ might correlate with the isotope's thermal neutron absorption cross section in some way.

A preliminary test electrode could be made from an alloy of CdPd. Cadmium-113(~ 12% abundance) has a large neutron absorption cross section of 20,000 barns, which translates to a threshold energy of only 0.086 MeV required for the collective deuterons to invade the cross sectional area:
CAUTION - n AT WORK ------- 14 - MeV neutrons, that is!

Or, a cathode could have slices of Pd or Ti (10-100μm) which alternate with perhaps 100 - 200 angstrom thick layers of the high neutron - absorbing element (B, In, Cd, or Gd) to serve as the "grain boundary" for the train of resonating deuteron waves. The idea is to test (example):

$$\mathbf{d + Cd^{113} \rightarrow Cd^{114}(0.06MeV) + p(6.76MeV)}, \text{ then}$$

$$\mathbf{p(\sim 6.76MeV) + d \rightarrow t(\sim 6.76MeV) + \beta^{+}(5.47MeV).}$$

Some cells could have a microwave flux applied to the electrode or target metal.

The development of a practical cold fusion device will want to promote with much efficiency the reaction $d + d \rightarrow He^4$ in the metal's electron cloud. Metals of choice that will alternate with layers of Pd or Ti will have a number of desirable properties. Two important ones are a large electron shell and a high mole density. Two metals that can be tested are platinum or gold.

Who knows? When it comes to cold fusion, the world may yet be able to "have its π and heat it too!"

In quantum field theory you state from the beginning that you have many, many species... If we try to understand the behavior of a fixed number of atoms that are supposed to be isolated from their surroundings, then we have bought ourselves a great deal of trouble. If instead we wish to prove a certain piece of a large mass, then there are no difficulties whatsoever with the measurement problem.

Martin Fleischmann

III. Sonoluminescence And Cold Fusion:

How To Get Your Entropy In Order

The theory of sonoluminescence presented will focus on some interesting facts about the phenomenon that were written by Carol White, editor - in - chief of *21st Century Science and Technology*, in a series of articles on sonoluminescence in the Winter 1991 issue (pages 26 - 32). She quotes extensively the researches and ideas of Dr. Seth Putterman (UCLA) and Dr. Lawrence Crum (U of Mississippi) and others. Some facts given are:

1. The repeated light emissions have a very short flash width of 50 picoseconds.

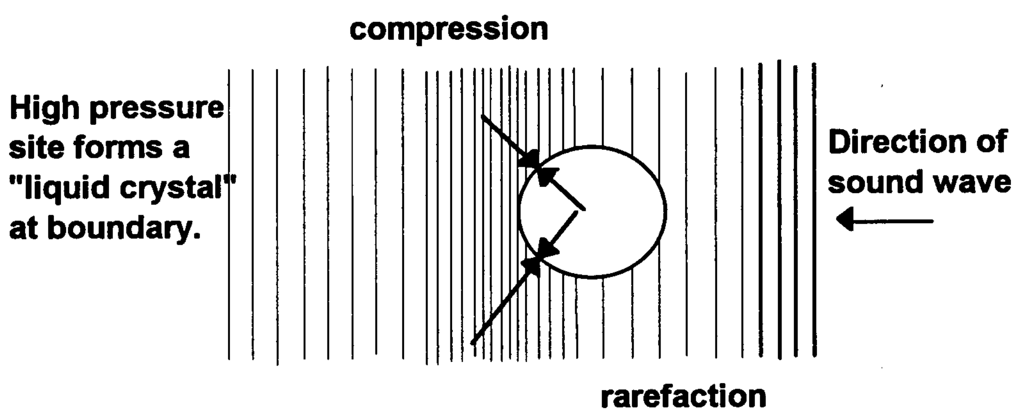
2. The emitted photons of blue light possess 3 electron volts each, a 10^{11} times energy magnification.

3. The bubbles vibrate between three and four times during each sound cycle (in which the sound frequency is about 20,000 cycles per second), but they emit a light pulse only once per cycle, at the point at which the bubble achieves its maximum volume.

4. The acceleration of the bubble as it expands from its minimum volume is 1 million times greater than its contraction at its maximum.

Statement (4) suggests an expansion time of about 50 picoseconds. That's because the period of frequency of a sound wave is $1/(2 \times 10^4$ seconds$) = 0.5 \times 10^{-4}$ seconds = 50 microseconds. Thus, the overall oscillation of a bubble (50 microseconds) is 10^6 times the period of expansion, if 50 picoseconds.

When the bubble has reached its maximum volume, it is proposed that a high compression of the liquid molecules at the bubble's boundary occurs, especially in the region forward of the expanding gas bubble where the bubble's surface becomes embedded in the compression phase of the sound wave, where a "liquid crystal" may form:



At the high compression sites surrounding the expanding gas bubble, the prediction is that the idea of entropy as "random motion" is temporarily replaced with a preferred coherent oscillation of a collection of particle waves.

Isaac Asimov wrote of entropy: "Entropy can be interpreted as a measure of the evenness with which energy is distributed. What's more, the evenness of energy distribution is 'most even', so to speak, when it is distributed as random motion among molecules."[8]

In Dr. Asimov's description, if one emphasizes the "evenness of energy distribution" among the molecules that are in the high - compression state at the surface of the