Brillouin Energy Corp.

THE CONTROLLED ELECTRON CAPTURE REACTION MODEL

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Many researchers have proposed that DD fusion occurs in metal hydride reactions despite the implausible energy levels required.

While physicists are very familiar with DD fusion as one way to release the Helium binding energy, the Brillouin Energy Controlled Electron Capture Reaction (CECR) model describes a more probable way to access this energy.

Many experimental results from metal hydride apparatus have characteristics in common with DD fusion. For example, the amount of helium formed corresponds to the heat released. A second correspondence is the formation of Tritium but at a drastically reduced ratio relative to Helium.

Many characteristics of the LENR heat reaction are at odds with the DD Fusion hypothesis. No Gamma is released. No fast neutrons are produced. Occasional excess heat production with light water palladium electrolytic systems. According to eminent physicists, the energy required to overcome the coulomb repulsion is impossible to achieve in a Pd lattice. However, it is possible to localize several MeV.

This paper describes a way to approach the problem that informs both reliable reactor designs and predicts the results that have been observed.

Several predictions can be made based on the CECR model. (2006)

- According to the CECR model, running the reaction with far fewer protons loaded in the matrix should be possible. Other groups claim a ratio of 85+% is required.
- According to the CECR model, initiating the reaction every time in milliseconds should be possible without waiting for unknown factors such as cosmic rays.
- According to the CECR model, releasing reaction heat and making Helium should be possible, starting with light water's protons instead of Deuterons.
- According to the CECR model, running the reaction in ordinary palladium, nickel, or tungsten should be possible regardless of grain structure.
- It should be possible to enhance electrolytic system output in high-pressure, high-temperature vessels.

All of the predictions from CECR have already been verified in Brillouin’s Second Round Data.pdf. Tom Claytor at LANL designed a test that produced tritium and SRI ran several tests. All Pd and 2 out of 3 Ni samples produced reaction heat.

The CECR Model is the only explanation consistent with verified research results. The model has made new predictions possible. Some of these predictions have already been experimentally validated. Notably, the model indicates how to build industrially useful devices.

Lacking knowledge of the physics underlying a phenomenon that is difficult to reproduce makes it almost impossible to gain control over it. Once physics is understood, it is a matter of engineering to control it and make it useful.

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1: INTRODUCTION

Robert E. Godes is the founder of Brillouin Energy Inc ("BE") and developer of the Intellectual Property ("IP") for Brillouin Energy Corp. In 1992, after looking at the sporadic evidence of energy production in "Cold Fusion" experiments, he realized that there was a common thread in the successful experiments. This started the formation of the Quantum Fusion hypothesis (sometimes simply referred to as "Quantum Fusion"). As of 2014, it is referred to as Controlled Electron Capture Reaction (CECR) or just Electron Capture Reaction (ECR). Godes realized that the reaction must involve electron capture as a natural energy reduction mechanism of the lattice. This endothermic reaction results in the formation of ultra-cold neutrons, probably $<10^{-15}$eV. The nearly stationary low energy neutrons accumulate onto other hydrogen nuclei moving in the lattice, leading to β^{-} decay. In 2005 Godes began to work full time creating IP and the hardware to demonstrate it. The purpose of this document is to explain the theory.

The hypothesis draws on wide ranging areas of study. Many different disciplines use the same equations but with different variable names, so this list is just drawing of the fields Robert Godes already had some familiarity with. It includes physics, thermodynamics, molecular mechanics, electrochemistry, material science, mechanics, several areas of electronics, and quantum mechanics. At first the information may seem disconnected and difficult to understand. However, by the end of chapter two, pieces should begin to fit together. It may require more than one pass to gain understanding of how the parts fit together.

Confusion in the field of "Cold Fusion" is due to the narrow focus required by researchers to advance knowledge in a specific discipline. Each researcher identifies a tree, but together they keep asking where the forest is. Recognition of how to drive the reaction requires broad areas of study in several disciplines and the ability to apply them all together. The CECR hypothesis lays out specific requirements for the material and environment in which the reaction will run. Understanding how to create the Nuclear Active Environment ("NAE"), a term coined by Ed Storms, involves concepts from several disciplines within the broad areas of chemistry, physics, and engineering. With this assembled, it is possible to drive the reaction across the entirety of a suitable material in a controlled fashion. Hence the name Controlled Electron Capture Reaction.

1.1 Some relevant history

At the 10th ICCF in 2003, Cravens and Letts presented a paper stating, “The general idea behind the cathode fabrication process is to create a uniform surface while increasing the Palladium grain size. Creating dislocations and defects with cold rolling is also important.”[1]

The two items, “increasing the Palladium grain size” and “Creating dislocations and defects”, are important if one is to stumble onto the reaction. It recognizes that lattice defects and grain size significantly affect the reliability of the reaction or effect occurring, without recognizing why. The why is discussed further in Section 2.12 captioned “Neutron Production via Electron Capture”.

At the same conference, people at SPAWAR (SPAce and naval WARfare center in San Diego, CA) and working with Scott Chubb, gave the following information that collaborates and expands on the findings above.

> “1.0 Introduction
> The characteristic feature of the polarized Pd/D–D2O system is the generation of excess enthalpy measured by calorimetry. However calorimetry alone cannot provide an answer to a number of questions, among them (i) continuous or discrete heat sources, (ii) their location, (iii) the sequence of events leading to the initiation of thermal events”

Later in section 2.2 Development of hot spots:

> “We note that (i) the rate of heat generation is not uniform, (ii) thermal activities occur at low cell temperature and at low cell currents, (iii) the intensity of thermal activity increases with an increase in both cell temperature and cell current” and “lattice distortion and the development and propagation of stresses within the Pd/D lattice.” [2]

Heat in a system is an indication of phononic activity. Even ions impacting and entering the lattice contribute to phonon activity. It is this passively generated phonon activity that causes the reaction to run in electrolytic systems where grains and dislocations allow superposition of a sufficient number

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[1] http://www.lenr-canr.org/acrobat/LettsDlaserstimu.pdf

[2] All quotes in this section are from http://www.lenr-canr.org/acrobat/SzpakSpolarizedd.pdf

of phonons on the order of 10^8. One exception to this passively generated phonon regime is Roger Stringham's sono-fusion devices. These devices appear to produce localized "Gross Loading", an explicit source of phononic activity and possibly electrons, but in an uncontrolled form. This overwhelms the lattice's ability to absorb the phononic energy released in the Quantum Fusion / neutron accumulation events. Roger also presented at the 10th ICCF and a quote from his poster session follows.

> "When a fusion event occurs, it usually takes place deep in the foil just after implantation generating in the trap an energy pulse that follows a channel of heat production rather than a gamma or some other energy dispersing mode. The heat pulse travels to and erupts from the surface as ejected vaporous metal with the resulting formation of vents in the target foil. These vent sites are easily found in FE SEM photos covering the foil's exposed surface."[3]

Roger Stringham uses collapsing sonoluminescence bubbles to drive the reaction. One must assume that the path traveled is the one created by the plasma jet of the collapsing bubbles impinging on the surface of the foil. Rogers's device also produced clear evidence of ^{4}He production at LANL in New Mexico and starts to produce reactions as soon as it is turned on. This is clear experimental evidence that the reaction is not limited to a surface effect. The CECR hypothesis easily accounts for this effect.

Cravens and Letts also provided a paper called "Practical Techniques in CF Research – Triggering Methods." This paper covers many of the ways people have found to increase the likelihood of getting the excess enthalpy or heat reaction. **The Quantum Fusion hypothesis explains all cases of excess enthalpy in the Cravens and Letts paper.**

Other facts in common are that nothing seems to happen in electrolysis experiments if the lattice is not loaded to greater than 85% of capacity[4]. At ICCF19 Coolescence reported production of foils with uniform grain structure that loaded to more than 90%. Note that none of these foils produced reaction heat. In material that does generate reaction heat, the more heat generated, the faster the metal comes apart. (See Figure1.) There is some evidence outside of Brillouin Energy of the phenomenon working with protium, even in Palladium. Palladium (Pd) was the first choice in early work.

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[3] Stringham, R. Cavitation and Fusion - poster session. in Tenth International Conference on Cold Fusion. 2003.

[4] http://www.newenergytimes.com/news/2007/NET21.htm#apsreport

Palladium is used as a filter for hydrogen because even helium will not pass through Pd — but hydrogen will. As atoms go, hydrogen is bigger than helium because the electrons in helium are more tightly bound to the nucleus by two protons. Therefore, for the hydrogen to pass through the palladium, it must travel as an ion. With a charge of one, that means it is a bare nucleus. In reality it carries a fractional charge, the ratio of electrons to H nuclei is fractional[5].

From the cold war and the development of the H-bomb, scientists "know how fusion works". The statement should be, "know one way that fusion works". Unfortunately, that view has blinded many to the possibility of other paths. Even within this "open to new ideas" community, a mindset seems to have developed that the phenomenon is deuterium deuterium or (DD fusion). It is not.

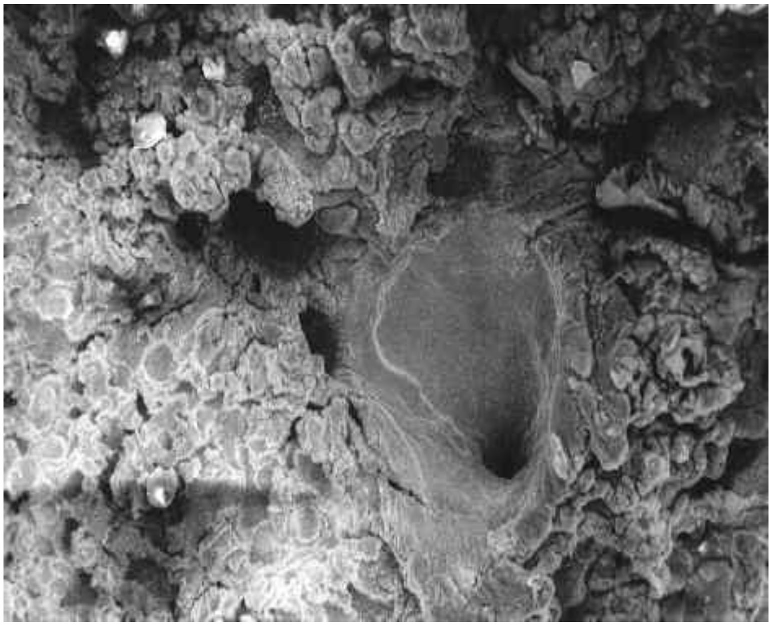

Figure 1: Sem image at 420x. shows a volcanic-like ejecta event where hot gaseous metal has been ejected from deep within the lattice[6]. This photo is based on a piece of core from one of Roger Stringham's sono-fusion devices.

There has been documented evidence of muon-catalyzed fusion. However, that explanation is unsatisfactory because muon-catalyzed fusion would be a surface phenomenon and not cause the eruptions from deep within the lattice as seen in Figure 1. Widom and Larsen also proposed low

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[5] Modeling of Surface and Bulk Effects in Thin-Film Pd Cathodes with High Proton Loading Nie Luo, George H. Miley*, Andrei G. Lipson Department of Nuclear, Plasma, and Radiological Engineering University of Illinois, at Urbana-Champaign, Urbana, IL 61801 USA http://www.lenr-canr.org/acrobat/LuoNmodelingof.pdf.

[6] http://www.d2fusion.com/education/eruptions.html.

energy neutrons but suggest “An electron e^{-} which wanders into a nucleus”[7] to create the low energy neutrons. They received a lot of attention, but the theory does not account for reactors like those built by Roger Stringham. Scott Chubb’s theory of superposition was appealing but does not seem to cover the full range of reactions observed, particularly strong heat generation using regular distilled water and NaOH. Peter Hagelstein has a very mathematically rigorous explanation for both localization of and dispersion of many MeV of energy[8]. I very much like Peter’s lossy spin boson model. Where Peter and I disagree is the path followed. It seems more likely that nature will follow the lower energy path of creating neutrons vs overcoming the coulomb barrier. Many people agree with Widom and Larsen on this point, it must be a weak nuclear force reaction. I personally just disagree with the source of the neutrons Widom and Larsen propose. What I outline in this paper is, what was a much more intuitive approach to explaining what was happening. This explanation also lends itself to directing how to build a practical device. Indeed, Tom Claytor performed his own first principals test of the information contained in this document. He told me of his tests in 2011. He apparently ran 12 tests and was able to produce tritium in all 12 tests.

The Quantum Fusion hypothesis predicts that it should be possible to stimulate excess heat in Pd using protium. It also shows that it should be possible to stimulate the response almost immediately without requiring what Brillouin Energy (BE) terms “Gross Loading”. BE has built several revisions of hardware to test the hypothesis. The early systems worked with ordinary distilled water and 0.3M to 3M (NaOH) as the electrolytic solution supplying the hydrogen to the “core”. The startup time is short (milliseconds), indicating light loading, and it is repeatable. The low temperatures and pressures of open beakers limit the achievable reaction rates and efficiencies in conversion of H to ^{4}He. (See Phase one verification data). In 2011 BE ran the reaction in a pressurized reactor at >1000 PSI. This experiment produced 2.1X and more than 150W of reaction heat.(See Brillouin Phase II data) The next sections will discuss the physics underlying Quantum Fusion and a path that leads to an understanding of the Quantum Fusion Hypothesis, including how the neutrons are created.

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[7] http://newenergytimes.com/v2/library/2006/2006Widom-UltraLowMomentumNeutronCatalyzed.pdf
This paper was published in THE EUROPEAN PHYSICAL JOURNAL C Received: 3 October 2005 Published online: 9 March 2006

[8] Hagelstein Peter L., and Chaudhary Irfan U. “Models Relevant to Excess Heat Production in Fleischmann-Pons Experiments.” Low-Energy Nuclear Reactions Sourcebook. Vol. 998. American Chemical Society, 2008. 249-267. ACS Symposium Series. http://www.lenr-canr.org/acrobat/Hagelsteinmodelsrele.pdf

2: HOW TO APPROACH THE REACTION

KEY CONCEPTS:

The following eight concepts work together in formation of the Nuclear Active Environment (“NAE”) for Low Energy Nuclear Reactions (“LENR”) process. This is what we call Electron Capture reaction or ECR

1) Phonons
2) First Brillouin zone
3) Molecular Hamiltonian
4) Nonbonding energy / Lennard-jones potential
5) Heisenberg Uncertainty Principle
6) Electron Capture
7) Electron orbital probability functions
8) Electromigration
9) Beta Decay

The following assertions are discussed and explained in the remainder of chapter 2. Item 1 has actually been proposed by others; however, their explanation of the path was not complete or even reasonable.

1 NEUTRON ACCUMULATION AND BETA DECAY

Quantum Fusion posits that the energy in these reactions is not the result of proton-proton interactions involving Coulombic force vs. the strong nuclear force but rather neutron accumulation, an exothermic reaction that result in the production of unstable ^{4}H. The ^{4}H then beta decays to ^{4}He, also an exothermic reaction. [Explained in section 2.1]

2 PRODUCTION OF COLD NEUTRONS VIA ELECTRON CAPTURE

The process starts with a dramatic increase of the phonon activity in the lattice. This increase in energy combined with the loading of Hydrogen drives the system out of equilibrium. Driving the system far from equilibrium causes the non-linear components of the Hamiltonian to dominate the energy of system. The systems, consisting of lattice atoms within at least the First Brillouin zone “the molecule” containing the nuclei that will undergo electron capture. The energy operator described by the Electron Capture Reaction Hamiltonian includes the Molecular Hamiltonian and two new terms to account for the extreme non-equilibrium conditions. The new terms are “Nonbonding energy or Lennard-Jones potential” (Section 2.7 captioned “Nonbonding energy or Lennard-Jones potential”) and “Heisenberg confinement energy” (Section 2.11 captioned “Heisenberg Confinement Energy”). These additional terms build the operator that achieves or exceeds 782 KeV, for a proton. Once this energy level is achieved neutron production via electron capture becomes favorable as a means of lowering the system energy. In the case of a deuteron, the energy may be up to 3MeV. This is an endothermic reaction that actually converts from 782KeV to 3MeV of energy to mass.

As the lattice cell loads, the Hamiltonian / energy in the lattice unit cell (molecule) is increased. As the palladium lattice absorbs hydrogen the metallic bonds literally stretch from the displacement / charge introduced by hydrogen nuclei to the point of the material visibly bulging.[9] This creates a sub lattice of hydrogen within the lattice of the host metal. This sub lattice is important because it affects phonon activity (Section 2.4 captioned “Phonons”) by significantly increasing the number of nodes to support phononic activity. In discussing palladium (Pd), S. Szpak and P. A. Mosier–Boss state,

> “Furthermore, the application of the Born–Haber cycle to the dissolution of protons into the lattice is *ca* 12 eV. Such a large magnitude of the “solvation energy” implies that the proton sits in deep energy wells while high mobility puts it in shallow holes. Thus, to quote: *“How can it be that the protons (deuterons) are so tightly bound yet they are virtually unbound in their movement through the lattice?*[10] *”*[11].

In the Quantum Fusion Hypothesis, the deep energy well is actually the energy well of the octahedral points not only between atoms, but between the n**p**$_{(n+1)}$**s** n**d orbital structures in the transition metals that seem to work.** In the s, p, and d electron orbitals, the energy level of the n**d** orbital is actually slightly above the energy level of the (n+1)**s** orbital. Metals with a filled or nearly filled n**d** orbital and or empty (n+1)**s** orbital provide just such an energy well. In nickel, a small amount of energy promotes the 4**s** electrons to the 3**d** energy level allowing hydrogen nuclei to occupy

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[9] The article http://www.physorg.com/news8690.html shows the displacement of the palladium lattice by hydrogen. Cashed version at http://www.brillouinenergy.com/A_Collection_of_information_on_Cold_Fusion/www-physorg-com/news8690.html Source: Penn State

[10] C. Bartomoleo, M. Fleischmann, G. Larramona, S. Pons, J. Roulette, H. Sugiura and G. Preparata, Trans. Fusion Technol., 26 23 (1994)

[11] THERMAL AND NUCLEAR ASPECTS OF THE Pd/D2O SYSTEM
Vol. 1: A DECADE OF RESEARCH AT NAVY LABORATORIES
S. Szpak and P. A. Mosier–Boss, eds.

the 4**s** sites. In Pd, the 5**s** shell is empty but the 4**d** shell is full[12], maximizing the effect and explaining palladium's remarkable ability to not only absorb hydrogen, but to filter it by allowing high mobility protons through the lattice. The hydrogen mobility in Pd can best be visualized with the hydrogen acting as the fluid in an external gear pump[13] where the 5**s** orbital energy wells are the space between the teeth, the 4**p** orbitals are the teeth, and the 4**d** orbitals are the casing.

Systems relying on passive phonon activity require lattice loading > 85%. Conventional thought is that this is evidence of the nuclei being forced together. However, there is also evidence that even under heavily loaded conditions the nuclei are farther apart than in H_2 or D_2 molecules. With the high mobility of hydrogen nuclei in the Pd lattice, the positive charges would slide around and away from each other. However it is possible for the relatively free moving hydrogen nuclei to individually be exposed to extraordinary forces. Exposure to extraordinary forces will **not** cause the wave function of a nuclei to spread out as in a Bose-Einstein condensate as proposed by Scott Chubb, but it will have an effect on it discussed in Section 2.12 captioned "Neutron Production via Electron Capture".

2.1 Fusion Without Proton-Proton Interactions

This brings us back to the concept of weak interaction. In the Quantum Fusion Hypothesis, the path to ^{4}He and other elements seen in Low Energy Nuclear Reaction (LENR) experiments is along the R and S-process lines of solar nucleosynthesis. The S-process, or slow-neutron-capture-process, is a nucleosynthesis process that occurs at relatively low neutron density and intermediate temperature conditions in stars. Under these conditions the rate of neutron capture by atomic nuclei is slow relative to the rate of radioactive beta-minus decay. A stable isotope captures another neutron but a radioactive isotope decays to its stable daughter before the next neutron is captured[14]. This process produces stable isotopes by moving along the valley of stability in the chart of isotopes[15]. The R-process, or rapid-neutron-Capture-process, is hypothesized as the source of approximately half of the neutron-rich atomic nuclei that are heavier than iron. The R-process entails a succession of rapid

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[12] http://www.webelements.com/palladium/atoms.html This link provides a good graphic of the electron energy levels half way down the page.

[13] http://www.pumpschool.com/principles/external.htm

[14] http://en.wikipedia.org/wiki/S-process

[15] http://www.nndc.bnl.gov/chart/ keep in mind what will be covered in sections 2.2 and 2.3

neutron captures on seed nuclei, or R-process for short. In the process of the useful Quantum CECReaction, low energy neutrons[16] accumulate, ending in a β^- decay described in the next section and the chart below. When seed nuclei are implanted in an active material such as Pd or Ni, it may be possible to produce longer life radioactive products. There are many documented examples of this phenomenon[17]. In the process of electron capture, each neutron created, from a proton that absorbed 782KeV to make up the mass difference. Conversion of a deuteron to a two-neutron system may require up to 3MeV to account for the loss of binding energy. Conversion of a triton to a three-neutron system may require up to 9.3MeV to account for the loss of binding energy but this seems extremely unlikely. While 782KeV or 3MeV energy barrier seems insurmountable, it is the reason the reaction is so difficult to reproduce if not addressed directly. Peter Hagelstein, a professor at MIT wrote a paper published in MIT's Research Laboratory of Electronics RLE 145 (29)[18]. Starting on page 24 Peter runs an analysis of and models the energy in a Pd – D system. In the second paragraph of page 25 he states "The result of the analysis indicates that the localization energy associated with a compact state is several MeV" indicating that it is entirely possible to localize the energy necessary for the path proposed in the Quantum Reaction Hypothesis. When the neutron(s) bond to another nuclei, the nuclear bonding energy is transferred to the lattice as phonons.

(Neutron + ^{1}H – ^{2}H) x c^2	=	02.237 MeV	=	0.358 Pico-joule
(Neutron + ^{2}H – ^{3}H) x c^2	=	06.259 MeV	=	1.003 Pico-joule
(Neutron + ^{3}H – (β^- + $\bar{\nu}_e$ + ^{4}He)) x c^2	=	17 - 20 MeV	=	2.7-3.2 Pico-joule

The path of the reaction when run with deuterium is

(Di-Neutron + ^{2}H => ^{4}H => β^- + $\bar{\nu}_e$ + ^{4}He + (17-20) MeV = (2.7-3.2) Pico-joule

Based on the Quantum Fusion Hypothesis, existing systems using deuterium will produce stronger reactions for two reasons. First they are more likely to obtain the required additional Heisenberg Confinement Energy[19] and second, because they are electron neutral. The system starts with two

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[16] See Neutron Production via Electron Capture

[17] "THE SCIENCE OF LOW ENERGY NUCLEAR REACTION" Edmund Storms 2007 Pg 97

[18] This report is available on MIT's website at http://www.rle.mit.edu/media/pr145/29.pdf.

[19] See section 2.11 Heisenberg Confinement Energy

neutrons and two protons in the form of two deuterons, and ends in ^{4}He, which has two protons and two neutrons. However, the path to ^{4}He is through the conversion of a deuteron to a dineutron[20][21]. A system made up of only two neutrons is not bound, though the attraction between them is very nearly enough to make them so.[22] This nearly bound state may also further reduce the energy required to drive an electron capture event in deuterium. The table above shows the path as single neutrons being added sequentially to build up P → D → T → ^{4}H. This may lead to other isotopes along the valley of stability of nuclei as reported by other researchers in this field. The higher energies required in the conversion of deuterium to a two-neutron system and tritium to a three-neutron system are achievable due to the larger size and mass of those ions within the lattice running the reaction. The interaction of created neutrons with other hydrogen ions in the system is much higher than interaction with lattice element nuclei for the following reasons. First hydrogen ions trapped in the systems that support the reaction, are held in the points farthest from the lattice element nuclei. On conversion to a neutron or neutron cluster the new ultra cold particle system is at the farthest point possible for interaction with lattice element nuclei. This in turn delays the transfer of energy from the lattice to the neutrons and places the neutrons in the exact location where a hydrogen ion is going to move to.

2.2 The ^{4}H Beta Decay Path

Why didn't anyone else go down this path? Several people did, but the first three pieces of information on the decay of ^{4}H that someone is likely to find will, in most cases, stop them from digging further into the National Nuclear Data Center (NNDC) or further pursuit on this path. The reward for further digging is finding the information shown in an excerpt from the paper "Data from Energy Levels of Light Nuclei A=4" in the next section. This data shows that if it were possible to produce ^{4}H at an energy level below 3.53MeV, it would likely undergo β^- decay and yield 17 to 20MeV of energy depending on the mass of ^{4}H. However, all the data in the NNDC is collected from high-energy physics experiments. The lowest energy level experiment that produced any indication of ^{4}H is an early sub-decay product of ^{7}Li(π^-,t)^{3}h+n. That is the result of an 8MeV pion colliding with

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[20] Dineutron cluster states in ^{18}O Phys. Rev. C 16, 475 - 476 (1977).

[21] See 2.12 Neutron Production via Electron Capture

[22] Bertulani CA, Canto LF, Hussein MS, The Structure And Reactions Of Neutron-Rich Nuclei, Physics Reports-Review Section Of Physics Letters 226 (6): 281-376 May 1993

* Funding will be necessary to properly study these phenomena.

^{7}Li. **The standard operating procedure of the NNDC is to list the lowest energy level of observation as the ground state.** So, the first three bits of information in the NNDC on ^{4}H shows the decay mode as n: 100% or as always undergoing a neutron ejection decay mode[23]. Also, because of the production mechanism, the ^{4}H nuclei is carrying away a significant portion of the reaction energy, giving it an apparent mass in excess of the possible bound state. This is the reason for the given energy range possible for β^{-} decay. **In a Quantum Fusion reaction, the neutron is cold (it just converted 782KeV to 3MeV to mass in the creation of a neutron, or di-neutron system) and the hydrogen nuclei is contained in a lattice with a mean free path < 200pm.**

Below is the data that one must find before beginning to accept this as a possible path for the reaction. Unfortunately, as stated above, the first three items someone is likely to find at the NNDC show the "ground state" of ^{4}H undergoing n:100% neutron ejection decay mode and that ^{4}H is an unbound nuclei. Again, in the NNDC, the "ground state" is considered to be the lowest state at which a nuclide has been observed. In the case of ^{4}H, that is the immediate aftermath ($\sim 10^{-22}$) sec after an 8MeV collision.

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[23] See http://www.nndc.bnl.gov/chart/reCenter.jsp?z=1&n=3.

2.3 Data from Energy Levels of Light Nuclei A=4

^{4}H Adopted Levels 1992Ti02 199807

Published: 1992 Nuclear Physics.

$Q_{\beta^-}=23.51\times10^{3}$ *11* $S_n=-2.91\times10^{3}$ *11* 1997Au07

History

Type	Author	Citation	Cutoff Date
Full evaluation.	H. Kelley, D. R. Tilley, H.R. Weller and G.M. Hale	Nuclear Physics A541 1 (1992)	8-Oct-1991

The stability of the first excited state of ^{8}Li against decay into ^{4}He+^{4}h (1988Aj01) sets an upper limit for B(^{4}h)≤3.53 MeV (see refs in 1992Ti02). This also sets a lower limit to the β^- decay energy ^{4}h-->^{4}He of 17.06 MeV. The upper limit of the β^- decay energy would be 20.06 MeV, if ^{4}h is stable against decay into ^{3}h+n. Estimates for the expected half-life of the β decay: if J^{π}(^{4}h)=0-, 1-, 2-, $T_{1/2}\geq10$ min; if J^{π} (^{4}h)=0+, 1+, $T_{1/2}\geq0.03$ s (see discussion in 1992Ti02). Experimentally there is no evidence for any β^- decay of ^{4}H, nor has particle stable ^{4}h been observed. Evidence for a particle-unstable state of ^{4}h has been obtained in ^{7}Li(π^-,t)^{3}h+n at 8 MeV 3 above the unbound ^{3}h+n mass with a width of 4 MeV. For other theoretical work see (1976Ja24, 1983Va31, 1985Ba39, 1988Go27).

The level structure presented here is obtained from a charge-symmetric reflection of the R-matrix parameters for ^{4}Li after shifting all the p-^{3}He E(λ) values by the internal Coulomb energy difference ΔE(Coulomb)=-0.86 MeV. The parameters then account well for measurements of the n-^{3}h total cross section (1980Ph01) and coherent scattering length (1985Ra32), as is reported in (1990Ha23). The Breit-Wigner resonance parameters from that analysis for channel radius a(n-t)=4.9 fm are given. The levels are located substantially lower in energy than they were in the previous compilation (1973Fi04), as will be true for all the T=1 levels of the A=4 system. The ^{4}Li analysis unambiguously determined the lower 1- level to be predominantly $^{3}p_{1}$ and the upper one to be mainly $^{1}p_{1}$; that order is preserved, of course, in the ^{4}h levels.

In addition to the given levels, the analysis predicts very broad positive-parity states at excitation energies in the range 14-22 MeV, having widths much greater than the excitation energy, as well as antibound p-wave states approximately 13 MeV below the 2- ground state. Parameters were not given for these states because there is no clear evidence for them in the data.

The structure given by the s-matrix poles is quite different, however. The p-wave resonances occur in a different order, and the positive-parity levels (especially for 0+ and 1+) are much narrower and lower in energy. It is possible that these differences in the s-matrix and K(R)-matrix pole structures, which are not yet fully understood, could explain the puzzling differences that occur when these resonances are observed in the spectra of multi-body final states.

This data sheet maybe retrieved from the NNDC at http://www.nndc.bnl.gov/ensdf/ in the box for “Retrieve all ENSDF datasets for a given nuclide or mass:” enter 4H. Click on the “Search” button. On the next page select the check box and click the HTML button.

2.4 Phonons

A phonon is a quantized mode of vibration occurring in a rigid crystal lattice, such as the atomic lattice of a solid. The study of phonons is an important part of solid-state physics because phonons play an important role in many of the physical properties of solids, such as thermal and electrical conductivity. In particular, the properties of long-wavelength phonons give rise to sound in solids — hence the name phonon. In insulating solids, phonons are also the primary mechanism by which heat conduction takes place. It may be easier to gain familiarity with phonon principals through study of sonar[24] and ultrasound[25]. In these systems the grain boundaries and defects are represented by the likes of thermoclines and variations in different types of tissue. Electrical engineers may be more likely to have familiarity with TDR or Time-domain reflectometry[26].

Phonons are a quantum mechanical version of a special type of vibrational motion, known as normal modes in classical mechanics, in which each part of a lattice oscillates with the same frequency. These normal modes are important because, according to a well-known result in classical mechanics, any arbitrary vibrational motion of a lattice can be considered as a superposition of normal modes with various frequencies; in this sense, the normal modes are the elementary vibrations of the lattice. Although normal modes are wave-like phenomena in classical mechanics, they acquire certain particle-like properties when the lattice is analyzed using quantum mechanics (see wave-particle duality[27]). Phonons are bosons possessing zero spin and may be in the same place at the same time.

Due to the connections between atoms, the displacement of one or more atoms from their equilibrium positions will give rise to a set of vibration waves propagating through the lattice. One such wave is shown in Figure2 below. The amplitude of the wave is given by the displacements of the atoms from their equilibrium positions. The wavelength λ is marked. [28]

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[24] http://en.wikipedia.org/wiki/Sonar#Sound_propagation

[25] http://en.wikipedia.org/wiki/Ultrasound

[26] http://en.wikipedia.org/wiki/Time-domain_reflectometer

[27] http://en.wikipedia.org/wiki/Wave-particle_duality

[28] http://www. en.wikipedia.org/wiki/Phonon.htm

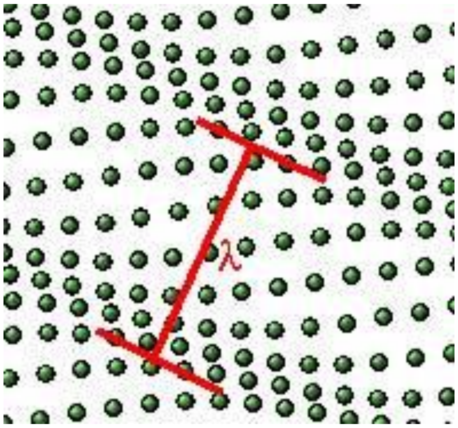

Figure 2 **Phonon Propagation Schematic**

Not every possible lattice vibration has a well-defined wavelength and frequency. However, the normal modes do possess well-defined wavelengths and frequencies.

The λ indicates crest to crest of a single wave function in a two-dimensional representation of a lattice. Figure 2 is only to aid in the visualization of the effect of phonons on a periodic potential. If one were to visualize the green dots as Pd atoms, then hydrogen atoms would be held in the octahedral points between the Pd atoms. Under gross loading conditions they would have a uniform distribution, but would still be significantly farther apart from each other than if they were in an H_2 or D_2 molecule. One of the more significant terms of the Molecular Hamiltonian is the potential energy arising from Coulombic nuclei-nuclei repulsions - also known as the nuclear repulsion energy. This is the force responsible for keeping matter from condensing into a single nucleus and is only addressed under nominal conditions in the Molecular Hamiltonian section. This component has extremely nonlinear behavior under compression conditions. These high compression conditions, where there is superposition of multiple phonon crests in lattice, will be discussed in Section 2.7 captioned "Non bonding energy or Lennard-Jones potential".

2.5 *First or irreducible Brillouin zone*

The atoms in direct contact with the first Brillouin zone are what the Quantum Fusion Hypothesis calls the molecule in section 2.6 captioned "Molecular Hamiltonian".

The following definition of "first Brillouin zone" is from http://en.wikipedia.org/wiki/Brillouin_zone.

In mathematics and solid-state physics, the first Brillouin zone is a uniquely defined primitive cell of the reciprocal lattice in the frequency domain. It is found by the same method as for the Wigner-Seitz cell in the Bravais lattice. The importance of the Brillouin zone stems from the Bloch wave description of waves in a periodic medium, in which it is found that the solutions can be completely characterized by their behavior in a single Brillouin zone.

Taking the surfaces at the same distance from one element of the lattice and its neighbors, the volume included is the first Brillouin zone. Another definition is as the set of points in k-space that can be reached from the origin without crossing any Bragg plane.

There are also second, third, etc., Brillouin zones, corresponding to a sequence of disjoint regions (all with the same volume) at increasing distances from the origin, but these are used more rarely. As a result, the first Brillouin zone is often simply called the Brillouin zone. (In general, the n-th Brillouin zone consists of the set of points that can be reached from the origin by crossing n − 1 Bragg planes.)

A related concept is that of the irreducible Brillouin zone, which is the first Brillouin zone reduced by all of the symmetries in the point group of the lattice.

2.6 Molecular Hamiltonian

"In atomic, molecular, and optical physics as well as in quantum chemistry, Molecular Hamiltonian is the name given to the Hamiltonian representing the energy of the electrons and nuclei in a molecule (*to be taken as a unit cell of the matrix including the trapped nuclei in which the reaction is running*). This "Hermitian operator[29]" and the associated Schrödinger equation play a central role in computational chemistry and physics for computing properties of molecules and aggregates of molecules such as conductivity, optical, and magnetic properties, and reactivity."[30]… By quantizing the classical energy in Hamilton form, one obtains a molecular Hamilton operator that is often referred to as the Coulomb Hamiltonian. This Hamiltonian is a sum of 5 terms.

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[29] Used in functional analysis and quantum mechanics. In quantum mechanics their importance lies in the physical observables such as position, momentum, angular momentum, spin, and the Hamiltonian, each represented by Hermitian operators on a Hilbert space. A Hilbert space generalizes the notion of Euclidean space in a way that extends methods of vector algebra from the two-dimensional plane and three-dimensional space to infinite-dimensional spaces.

[30] http://en.wikipedia.org/wiki/Molecular_Hamiltonian (*added by Brillouin Energy)*

They are:

1. The kinetic energy operators for each nucleus in the system;
2. The kinetic energy operators for each electron in the system;
3. The potential energy between the electrons and nuclei - the total electron-nucleus Coulombic attraction in the system;
4. The potential energy arising from Coulombic electron-electron repulsion
5. The potential energy arising from Coulombic nuclei-nuclei repulsions - also known as nuclear repulsion energy.

1. $$\hat{T}_n = -\sum_i \frac{\hbar^2}{2M_i}\nabla^2(\mathbf{R}_i)$$

2. $$\hat{T}_e = -\sum_i \frac{\hbar^2}{2m_e}\nabla^2(\mathbf{r}_i)$$

3. $$\hat{U}_{en} = -\sum_i\sum_j \frac{Z_i e^2}{4\pi\epsilon_0\left|\mathbf{R}_i - \mathbf{r}_j\right|}$$

4. $$\hat{U}_{ee} = \frac{1}{2}\sum_i\sum_{j\neq i} \frac{e^2}{4\pi\epsilon_0\left|\mathbf{r}_i - \mathbf{r}_j\right|} = \sum_i\sum_{j>i} \frac{e^2}{4\pi\epsilon_0\left|\mathbf{r}_i - \mathbf{r}_j\right|}$$

5. $$\hat{U}_{nn} = \frac{1}{2}\sum_i\sum_{j\neq i} \frac{Z_i Z_j e^2}{4\pi\epsilon_0\left|\mathbf{R}_i - \mathbf{R}_j\right|} = \sum_i\sum_{j>i} \frac{Z_i Z_j e^2}{4\pi\epsilon_0\left|\mathbf{R}_i - \mathbf{R}_j\right|}.$$

Here M_i is the mass of nucleus *i*, Z_i is the atomic number of nucleus *i*, and m_e is the mass of the electron. The Laplace operator of particle *i* is:

$$\nabla^2(\mathbf{r}_i) \equiv \boldsymbol{\nabla}(\mathbf{r}_i)\cdot\boldsymbol{\nabla}(\mathbf{r}_i) = \frac{\partial^2}{\partial x_i^2} + \frac{\partial^2}{\partial y_i^2} + \frac{\partial^2}{\partial z_i^2}$$

Since the kinetic energy operator is an inner product, it is invareant under rotation of the Cartesian frame with respect to which x_i, y_i, and z_i are expressed.[31]

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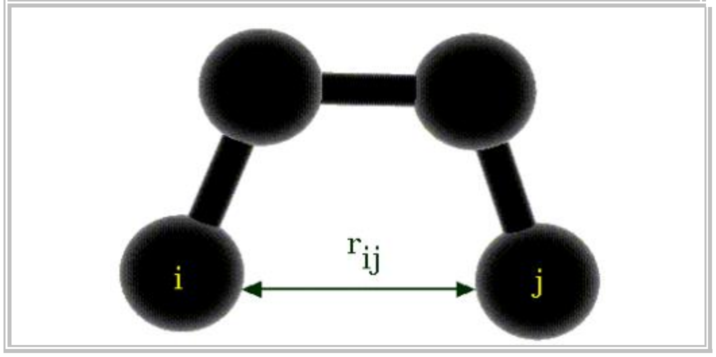
[31] http://en.wikipedia.org/wiki/Molecular_Hamiltonian

2.7 Nonbonding energy or Lennard-Jones potential

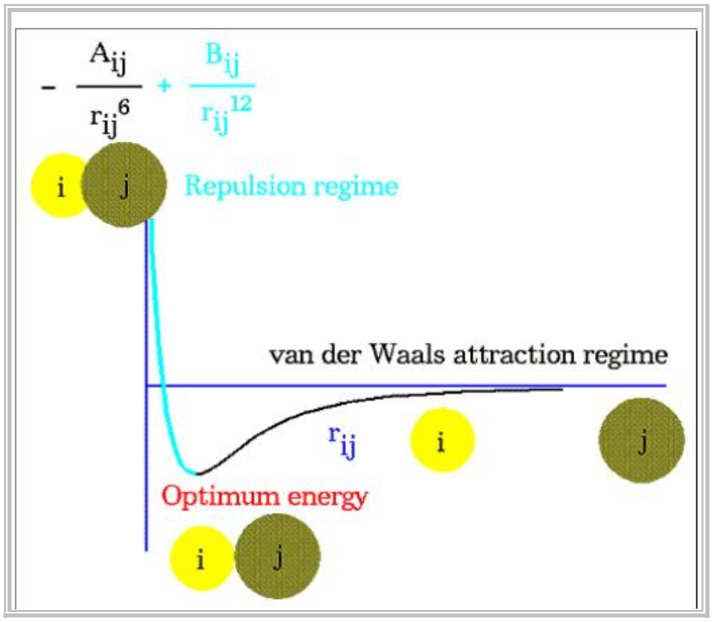
The fifth entry in the description of the Molecular Hamiltonian is the description of the undisturbed system. When the molecular system experiences significant compression distortion, nonlinear effects begin to dominate this fifth component. Below is a discussion of the potential energy arising from Coulombic nuclei-nuclei repulsions as it transitions to non-bonding energy type of interaction. The term non-bonded energy refers specifically to atoms that are not bonded to each other as indicated in the picture below, but the x/r^{12} relationship also follows for bonded atoms. It is not addressed for bonded atoms because the interaction between non-directly bonded atoms can absorb so much energy before there is any significant effect on the bonded atoms. It is this effect formed by the interaction of multiple phonons that is a large driver of electron capture events.

From http://cmm.info.nih.gov/modeling/guide_documents/molecular_mechanics_document.html (now a 404)
See Alternative notations of the Lennard-Jones potential
The non-bonded energy represents the pair-wise sum of the energies of all possible interacting non-bonded atoms i and j:

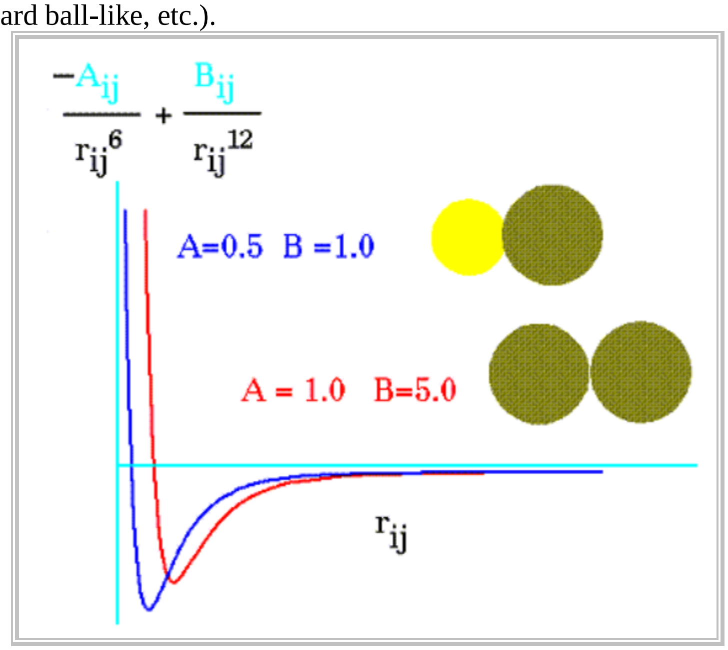
$$E = \underbrace{\sum_i \sum_j \frac{-A_{ij}}{r_{ij}^{6}} + \frac{B_{ij}}{r_{ij}^{12}}}_{\text{van der Waals term}} + \underbrace{\sum_i \sum_j \frac{q_i q_j}{r_{ij}}}_{\text{Electrostatic term}}$$



The non-bonded energy accounts for repulsion, van der Waals attraction, and electrostatic interactions. van der Waals attraction occurs at short range, and rapidly dies off as the interacting atoms move apart by a few Angstroms. Repulsion occurs when the distance between interacting atoms becomes even slightly less than the sum of their contact radii. The energy term that describes attraction/repulsion provides for a smooth transition between these two regimes. These effects are often modeled using a 6-12 equation, as shown in the following plot:



The "A" and "B" parameters control the depth and position (interatomic distance) of the potential energy well for a given pair of non-bonded interacting atoms (e.g. C:C, O:C, O:H, etc.). In effect, "A" determines the degree of "stickiness" of the van der Waals attraction and "B" determines the degree of "hardness" of the atoms (e.g marshmallow-like, billiard ball-like, etc.).



The "A" parameter can be obtained from atomic polarizability measurements, or it can be calculated quantum mechanically. The "B" parameter is typically derived from crystallographic data so as to reproduce observed average contact distances between different kinds of atoms in crystals of various molecules.

2.8 Electromigration - Quantum compression

One of the methods used by Brillouin Energy Corp., and the one that will be used first in a pressurized reactor vessel, is to aid stimulation of phononic activity by introducing Quantum compression pulses or Q pulses. These impulses through the core of the reactor can achieve current densities of 10^5 or more Amps per cm^2 due to skin effect. The current density of the Q pulses causes electromigration of core lattice elements and interstitial ions. This momentum transfer between conducting electrons and core lattice elements drives the values of the evaluated Hamiltonian to the magnitude required for electron capture events. The Q pulses in the first test of the Quantum Fusion Hypothesis were 4A peak and 40ns wide in a Pd wire 0.05mm in diameter. This corresponds to a current density of over $2000A/mm^2$ in the core material. The control systems currently in operation are capable of producing pulses up to 150A peak 20ns wide. This lattice element displacement activity also provides broadband phonon excitation activating all possible phonon modes of the lattice.

The Q pulse transfers momentum to the core lattice and the nuclei to undergo electron capture. They also provide an explicit source of electrons for electron capture. In the first test of the Quantum Fusion Hypothesis, a 1nF capacitor was used with a voltage of 240.4V and a frequency of 100KHz. The Q pulse energy was calculated as ½ CV^2 Hz. The energy loss in the 1Ω .1% 50ppm RN55C01R0B resistor used to measure the 4A peak was not included as a loss in the energy calculation. The above calculation shows an RMS value of only 12mA for the Q pulse current.

2.9 Skin effect

The extremely high frequency nature of the Q pulses causes a phenomenon known as skin effect. Skin effect is the tendency of a current pulse to distribute itself so that the greatest current density is near the surface. That is, the electric current tends to flow in the "skin" of the conductor.

The skin depth d can be calculated as follows:

$$d = \sqrt{\frac{2\rho}{\omega\mu}}$$

where

ρ = resistivity of conductor

ω = angular frequency of current = $2\pi \times$ frequency

μ = absolute magnetic permeability of conductor $= \mu_0 \cdot \mu_r$, where μ_0 is the permeability of free space and μ_r is the relative permeability of the conductor.

Skin effect ordinarily represents a problem to overcome. It is a problem Robert E. Godes worked around several times in solving electronics design problems earlier in his career. Knowledge of this effect can also be exploited to aid in promoting phonons and reactions at the surface of the core material. Skin effect aids in producing reactions by providing electrons and electromigration phonons at the surface. These are two of the critical elements required to run the reaction with protium under the light loading conditions required to maintain core integrity. This will have more meaning in Section 2.12-captioned "Neutron Production via Electron Capture".

2.10 *The Heisenberg Uncertainty Principle*

The Heisenberg uncertainty principal states $\Delta\rho\ \Delta q \geq h / 4\pi$[32] where
Δq is the uncertainty or imprecision (standard deviation) of the position measurement.
$\Delta\rho$ is the uncertainty of the momentum measurement in the q direction at the same time as the q measurement.
h is a constant from quantum theory known as Planck's constant, a very tiny number.
π is pi from the geometry of circles.
$\geq$ means "greater than or equal to."

The first solid (no pun intended) example was the Bose Einstein condensate. "The first "pure" Bose–Einstein condensate was created by Eric Cornell, Carl Wieman, and co-workers at JILA on June 5, 1995. They did this by cooling a dilute vapor consisting of approximately 2000 rubidium-87 atoms to below 170 nK".[33] That is 0.00000017 degrees above absolute zero equal to -273.15°C. This has the effect of making $\Delta\rho$ very small and, as predicted by quantum mechanics and the Heisenberg uncertainty principal, the standard deviation of the position became quite large, to the point that the 2000 atoms were nearly visible to the naked eye.

2.11 *Heisenberg Confinement Energy*

The "Heisenberg Confinement Energy" is a coined term. The Quantum Fusion hypothesis attributes the combination of stress from loading hydrogen, phonon compression of the lattice, non-bonding energy, and the terms of the molecular Hamiltonian, causing the formation of a "Coulombic box." The "Coulombic Box" is actually a combination of Coulombic repulsion terms from the other nuclei

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[32] http://www.aip.org/history/heisenberg/p08a.htm

[33] http://en.wikipedia.org/wiki/Bose-Einstein_condensate

in the system and confinement by electron orbital wave shells. A deuteron is one proton bonded to one neutron. The bonding energy is ~2.2MeV which means the size of a deuteron is not twice the size of a proton, but it is significantly larger than a proton. A deuteron absorbing a neutron releases ~6MeV in bonding energy, making it not 33% larger than a deuteron but significantly larger. This larger size further enhances the Heisenberg Confinement Energy. This statement is supported by the fact that all forms of hydrogen will pass through a Pd foil, but Protium is absorbed much more easily than Deuterium, which loads more easily than Tritium. In fact, 1% protium in D_2O will result in almost 10% protium loading into a Pd cathode.[34]. The reduced mobility of Tritium over Deuterium over Protium is a function of the limited physical size of the vacant energy level in the 5**s** energy band. This energy/physical gap is formed by the interaction of the 4**p** and 4**d** orbital probability functions in Palladium. This "box" causes Δq or standard deviation of the position measurement to be severely constrained. This constraint causes Δρ to provide the remaining mass/energy required to make an electron capture event energetically favorable. This energy is what is referred to as the Heisenberg Confinement Energy. The principle behind this energy is the same as that used to create the Bose Einstein condensate, only reducing Δq instead of Δρ. This is also the reason that hot spots form and burn out, particularly under "Gross Loading" conditions. "Gross Loading" requires the superposition of several passively generated phonons. Phonons are reflected by grain boundaries and defects. The larger size of the deuterium nuclei allows the required reduction in Δq to be achieved more easily even though deuterium may require up to 3MeV vs. 782KeV for protium. The slightly larger size causes deformation of the lattice electron wave functions and the "Heisenberg Confinement Energy" is a 1/x type function that increases exponentially once the inflection point is reached.

2.12 Neutron Production via Electron Capture

This is where the defects and grain size of the lattice come into play in "Cold Fusion" experiments not employing or making use of the Quantum Fusion Hypothesis. These experiments depend on what Brillouin Energy terms "Gross loading" or loading in excess of 85% of the lattice. By performing "Gross Loading" the stress and strain in the lattice raise the energy of the equilibrium Hamiltonian. The grain boundaries and defects reflect phonon energy, and the intersection of enough reflections

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[34] "THE SCIENCE OF LOW ENERGY NUCLEAR REACTION" Edmund Storms 2007 Pg 132 Figure 66

allow the reactions to start. With gross loading, the first bonding event gives off more phonons, causing more reactions in the immediate grain or boundary area. The high phononic activity breaks lattice bonds and/ or rearranges grains or boundaries until reactions are no longer sustainable in that area.

It is the combination of the terms discussed in Section 2.4, captioned "Phonons", through Section 2.11, captioned "Heisenberg confinement energy", that allows the Quantum Fusion reaction to run. **Any material with a unit cell or molecule able to include reactant nuclei and obtain or exceed a Molecular Hamiltonian of 782KeV to 9.3MeV has the potential to run the Quantum Fusion process**, providing the unit cell has conduction or valence band electrons available for capture. The electron capture event is a natural reduction in energy of this system instantly removing from 782KeV to 9.3MeV of energy from the unit cell or molecule. That energy is the removal of a proton from the bounding "Coulombic box", conversion of energy to mass, and replacement of bonding energy within the nucleus. As the lattice breaths the compression cycle is where the electron capture events occurs but after the capture event the relaxation cycle leaves the newly formed neutron in a vacuum resulting in a low energy neutron(s) - low enough that the cross section allows it to combine with nearby or migrating hydrogen nuclei. The distance between the lattice nuclei and the migrating hydrogen atoms make the probability of combining with another hydrogen much higher than combining with a lattice element.

One of the reason deuterium seems to be required is that hydrogen enters the lattice as an ion and, by using deuterium, the reaction is a two-step process. A deuteron undergoes electron capture resulting in a low energy dineutron. The dineutron interacts with a deuteron to create ^4H and then undergoes a beta decay releasing an electron, restoring the charge previously captured. The reaction starts and ends with two protons and two neutrons. When working with protium, an explicit source of electrons must be supplied as the reaction starts with four protons and **no** neutron but ends with **two** of each resulting in a net absorption of two electrons for each ^4He created. This is one advantage of using Q pulses to run the reaction. The Q pulse:

1) Produces intense phononic activity.
2) Eliminates the need for "Gross loading."
3) Provides an explicit source of electrons.
4) Causes the reaction to run on the surface of the lattice there by improving the removal of heat and reducing lattice destruction.

This also points out some major pitfalls of the "Gross loading" technique. By heavily loading the lattice:

1. The first electron capture event removes 782KeV, but when a dineutron fuses with a deuteron, 17 to 20MeV of energy is released in the process of β^{-} decay.
2. This initially causes a chain reaction of electron capture events in the vicinity of this first reaction.
3. As the population of ^{4}H builds, the number of β^{-} decay events exceed the ability of the lattice to absorb this energy. (See Figure 1)
4. This destruction continues until the lattice can no longer support the reaction in that area.
5. Exceeding the ability of the lattice to absorb phononic energy may cause the reaction to release some undesirable high-energy particles potentially representing hazardous / non-useful energy.
6. Item number 4 above will cause the failure of the device.
7. Item number 5 above will possibly lead to low-level radioactive products.

2.13 Phonons and Energy Dissipation

Just as phonons are able to bridge the scale factor between atomic and nuclear scales to affect an electron capture, they also allow that energy to be carried away.

Shortly before his death in 1993, Julian Schwinger wrote a note talking about cold fusion and specifically phonon scale and energy transfer mechanisms accounting for the energy dissipation, although he never quite recovered from the "we **know** how fusion works" mindset of the H-bomb. In that note Julian states,

"The initial stage of one new mechanism can be described as an energy at the nuclear level from a DD or a PD pair and transfers it to the rest of the lattice, leaving the pair in a virtual state of negative energy. This description becomes more explicit in the language of phonons. The non-linearity's associated with large displacement constitutes a source of the phonons of the small amplitude, linear regime. Intense phonon emission can leave the particle pair in a virtual negative energy state."[35] In the previous section 2.12 captioned "Neutron Production via Electron Capture". The following six concepts work together in driving the electron capture process.

1. Phonons
2. Molecular Hamiltonian
3. Nonbonding energy
4. Heisenberg Uncertainty Principle / confinement energy.

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[35] Energy Transfer In Cold Fusion and Sonoluminescence by Professor Julian Schwinger http://www.brillouinenergy.com/Energy_Transfer_In_Cold_Fusion_and_Sonoluminescence.doc

5. Electron orbital probability functions
6. Electromigration

The Electron Capture event converts from 782KeV up to 9.3MeV in Hamiltonian energy to mass in the neutron(s). It also removes a unit of positive charge. This proton was a significant addition to the Coulombic nuclei-nuclei repulsions portion of the Non-bonding energy portion of the Molecular Hamiltonian. In the process of Beta Decay, that nucleon charge is restored to the system. The appearance of the positive charge in the molecular system is accompanied by the prompt increase of Non-bonding / Lenard Jones effect energy component of the Molecular Hamiltonian. This results in phonons that transfer the energy to the lattice. When the system is working under “Gross Loading” conditions, lattice bonds break from too many reactions in too small an area too quickly. This may lead to the sporadic sighting of neutrons. Edmund Storms raises the question of why β^- radiation is not seen and asks for an explanation of occasional X ray emissions. One possible explanation is that the mean free path of electrons in a conductor (familiar to electrical engineers) causes the absorption of β^- radiation through direct nucleon interaction and the formation of additional phonons. The occasional X ray source has to do with location of the nuclear events possibly stimulating the X ray emissions from lattice elements.

3: HOW THE QUANTUM FUSION HYPOTHESIS WAS TESTED

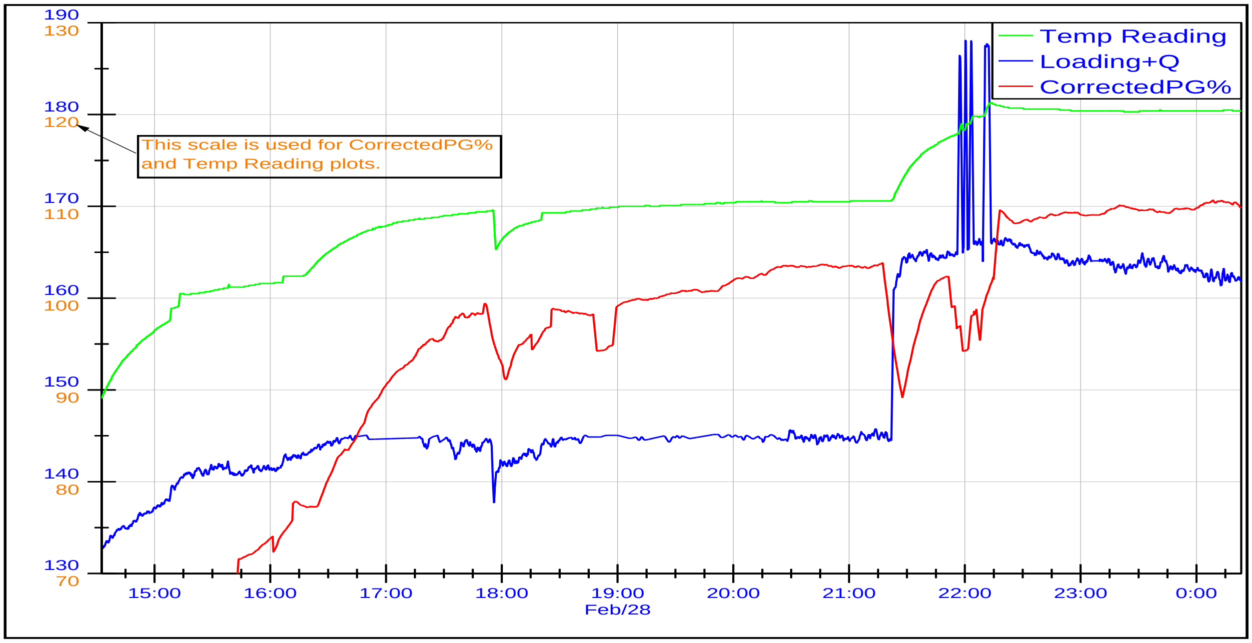
With this hypothesis in mind, a test device was built. The first device was eventually able to produce an 80ns wide 4A pulse with 20ns rise and fall times and a 100KHz repetition rate. This represents a peak current density of just over 2000A per mm^2 in the 0.05mm diameter palladium wire used while supplying only 16mA RMS current to the wire. In that wire 16mA RMS equals ~8.15A/mm^2 RMS. For comparison, the wire would start to glow at ~305A/mm^2 RMS equal to 0.6A or 600mA RMS. The wire resistance was ~2Ω indicating that the Quantum compression energy (Q or Q pulses) was not a significant source of energy into the system. The calculation for power input causing the rise of the water temperature was based on ½CV^2*Hz. This is the total energy theoretically possible based on the capacitor and the voltage available. The energy absorbed by the 1Ω resistor used to measure the current and numerous other losses were ignored. Using I^{2}R to calculate the energy into the core it would appear that Q was really only responsible for ~0.5mW. The calculation used was ½CV^2*Hz = 2.35W. This higher total energy theoretically possible value was used to increase my confidence of the effect possibly having commercial value.

As was stated above in section 2.12 captioned "Neutron Production via Electron Capture"., Q provides both phonons and an explicit source of electrons. With weak Q pulses and operating in a copper pipe cap used as the anode, the energy calculations came out near 70%. Granted, electrolysis energy and loss to radiation were not being considered, but the loss was too great to indicate nuclear energy. The cup was forming green blue crystals, probably copper (II) chloride 2-H_2O with the chlorine coming from the tap water. By switching to Pyrex measuring cup and increasing Q pulses to 4A amplitude 40ns duration, the system became nearly 100% efficient even ignoring the losses of thermal radiation to the environment, electrolysis, and Q losses. The Hypothesis was well enough confirmed for the time available.

4: STATUS

Brillouin Energy now has pending U.S.[36] and international patent applications prepared and filed. These include an application describing systems along the lines of what is described above, and applications on specific portions of the drive system. The individual country filing fees have been covered in Japan, China, India, and the EU for the first patent that was granted.

In August 2009 Brillouin Energy Corp. opened a lab in Berkeley, CA with a 1-liter pressure vessel, LabVIEW data collection and control system, Fluke Scope Meter ACrms+DC to measure the power flowing into the system. LabVIEW controls multiple power supplies and the processor controlling the high speed switching of power signals to the pressure vessel. Approximately 20 parameters get recorded every 10 seconds and used to create graphs like this one using data taken on February 28 that shows the first time the “excess heat” exceeded 100%. This means the “watts out” were twice the “watts in.” using full calorimetric techniques.



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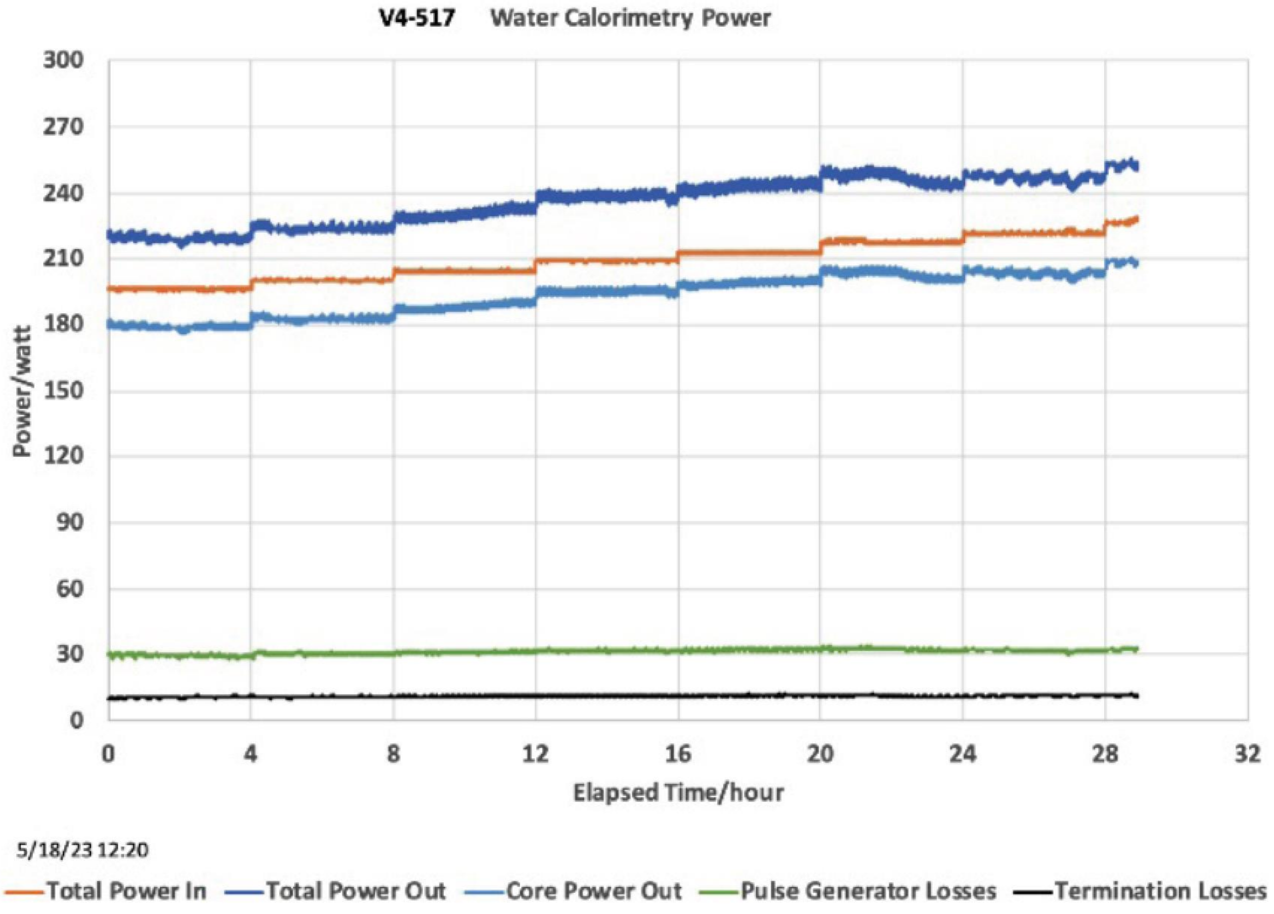
[36] APP. NO. 20070206715.

In May of 2023 we were able to reliably capture more thermal energy in water than electric power provided to the reactor. This was verified by Fran Tanzela and is from his presentation at ICCF 25. This shows more thermal energy in water, the top dark blue line, compared to the total electrical energy into the system, the orange line.



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4.1 Next phase

Work continues progressing on control systems and calorimeters to improve data collection and calibration. This allows much better replication and automated test. We are now in our 4th round of funding to open our own manufacturing facility. This will allow us to further define all the manufacturing parameters required to make this technology industrially useful. Up until this point making a catalyst required transporting the part between 5 or more different shops. Having so many different locations running only every few months made repeatable product imposable. That is all changing now.

5: THE PLAN 11-2023

We expect it to take up to 10 months to complete the setup of manufacturing equipment. The near-term goal is the ability to manufacture 10 catalyst rods per day. This will allow cycles of learning and the ability to stabilize the manufacturing process.

5.1 Scope of work

1. Develop assembly and processes for construction of industrially useful systems.
2. Determine the achievable energy density of the catalyst operating at 700°C.
3. Develop drive signal specifications in relation to catalyst cross section.
4. Develop equations or tables to relate required waveforms to core profiles, temperatures, and pressures.
5. Advance technology to the point where systems can be assembled from bins of parts where 99.9+% operate correctly.
6. Assemble design package that would allow potential licensees to design products.
7. Finish development of lab sized demonstration systems in two versions, Calorimetric and Boiler systems.

6: SUMMARY

6.1

✓ **Phase One.** Brillouin Energy Corp. constructed a reactor control system capable of producing Quantum Fusion events in an open container, allowing the principles of the Brillouin Energy hypothesis to be demonstrated.

Phase Two. Brillouin Energy has obtained Quantitative results on a ***commercially viable*** means of producing industrially useful heat using our technology.

Phase Three. Brillouin Energy is establishing the first full manufacturing development facility in California and is looking to establish an East Coast operation to tap additional talent and distribute knowhow. The East Coast operation is being established to both reduce risk to the completion of the technology and speed time to market.