

The Quantum Fusion Hypothesis

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Ignorance of the physics underlying a phenomenon that is difficult to reproduce makes it almost impossible to gain control over that phenomenon. Once the physics is understood, it is a matter of engineering to control it and make it useful. It is my hope that by publishing, the technology will be universally available to improve the human condition.

1. INTRODUCTION

Robert E. Godes is the founder of Profusion Energy, Inc. ("PE") and developer of the Intellectual Property ("IP") for PE. 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"). Godes realized that the reaction must involve electron capture as a natural energy reduction mechanism of the lattice. This would cause low energy neutrons to accumulate onto other hydrogen nuclei, 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 including physics, 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 Section 2, pieces should begin to 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 Quantum Fusion 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") 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.

1.1 Some relevant history

At the 10th International Conference on Cold Fusion (ICCF10) in 2003, Dennis Cravens and Dennis 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.

At the same conference, researchers from SPAWAR (SPace and Naval WARfare Center in San Diego, California) gave the following information that collaborates and expands on the findings above:²

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. . . [From the Introduction]

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. . . lattice distortion and the development and propagation of stresses within the Pd/D lattice. [Section 2.2]

Heat in a system is an indication of phonon 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 existing systems where grains and dislocations allow superposition of a sufficient number of phonons. One exception to this passively generated phonon rule is Roger Stringham's sonofusion devices.³ 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 events. Stringham also presented at ICCF10 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

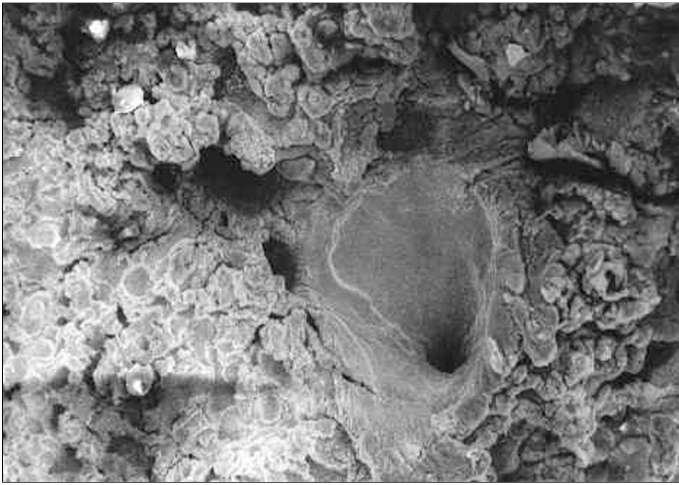


Figure 1. SEM image at 420x.

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.

One must assume that the path traveled is the one created by the plasma jet impinging on the surface of the foil. Stringham's device also produced clear evidence of ^4He production at LANL in New Mexico and starts to produce reactions as soon as it is turned on.

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 this 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 The more heat generated, the faster the metal comes apart. (See Figure 1.) There is some evidence of the phenomenon working with protium, even in palladium. Palladium (Pd) was the first choice in early work.

Palladium is used as a filter for hydrogen because even helium will not pass through Pd—but hydrogen will. As atoms go, hydrogen is actually 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, but 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 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 sonofusion 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 propose low energy neutrons but suggest "An electron e^- which wanders into a nucleus"⁷ to create the low energy neutrons. They have received some rather harsh criticism.⁸ Scott Chubb's theory of superposition is appealing but does not seem to cover the full range of reactions observed, particularly strong heat generation using regular distilled water and NaOH. So, if there is no good way, other than Chubb's, to explain overcoming the coulombic repulsion, it must not be a strong nuclear force reaction. Therefore—and many people agree with Widom and Larsen on this point—it must be a weak nuclear force reaction.

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 Profusion Energy (PE) terms "gross loading." PE has built several revisions of hardware to test the hypothesis. These systems work 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 repeatable, although it has only been tested with as drawn Pd (99.9%) and Ni270 in open beakers. The low temperatures and pressures of open beakers limit the achievable reaction rates and efficiencies in conversion of H to ^4He . 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.

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:

- 1) Phonons
- 2) First Brillouin zone
- 3) Molecular Hamiltonian
- 4) Non-bonding energy
- 5) Heisenberg Uncertainty Principle
- 6) Electron capture
- 7) Electron orbital probability functions
- 8) Electromigration
- 9) Beta decay

These assertions are explained in the following subsections. Item 1 has actually been proposed by others, however their explanation of the path was not complete or even reasonable.

Quantum Fusion posits that the energy in these fusion 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 ^4H . The ^4H then beta decays to ^4He , also an exothermic reaction. [Explained in Section 2.1.]

The process starts with the instigation of phonons in the lattice. This raises the Hamiltonian of a system consisting of the lattice atoms in direct contact with the First Brillouin zone "the molecule" containing the nuclei to undergo electron capture. When the Molecular Hamiltonian, including non-bonding energy and "Heisenberg confinement energy" (Section 2.11), achieves or exceeds 782 KeV, neutron production via electron capture becomes favorable as a means of lowering system energy. This is an endothermic reaction

that actually converts 782 KeV of energy to mass.

As the lattice cell loads, the Hamiltonian/energy in the lattice unit cell (molecule) is increased. The lattice in palladium can absorb so much hydrogen that the metallic bonds literally stretch from the displacement/charge by hydrogen nuclei, to the point of the material visibly bulging. 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) by significantly increasing the number of nodes to support phononic activity. In discussing palladium (Pd), S. Szpak and P.A. Mosier-Boss state:⁹

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

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 $P_n S_{(n+1)} D_n$ orbital structures in the transition metals that seem to work. In the S, P, and D electron orbitals, the energy level of the D_n orbital is actually slightly above the energy level of the $S_{(n+1)}$ orbital. Metals with a filled or nearly filled D_n orbital and or empty $S_{(n+1)}$ orbital provide just such an energy well. In nickel, a small amount of energy promotes the $S_{(4)}$ electrons to the D_3 energy level allowing hydrogen nuclei to occupy the $S_{(4)}$ sites. In Pd, the $S_{(5)}$ shell is empty but the D_4 shell is full,¹¹ maximizing the effect and explaining palladium’s remarkable ability to not only absorb hydrogen, but to filter it by allowing high mobility through the lattice. The hydrogen mobility in Pd can best be visualized with the hydrogen acting as the fluid in an external gear pump¹² where the $S_{(5)}$ orbital energy wells are the space between the teeth, the P_4 orbitals are the teeth, and the D_4 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).

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 4He and other elements seen in 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.¹³

This process produces stable isotopes by moving along the valley of beta stability in the chart of isotopes.¹⁴ 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 neutron captures on seed nuclei, or R-process for short. In the process of cold fusion, or the expected to be useful Quantum Fusion reaction, low energy neutrons¹⁵ 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, longer life radioactive products may be produced. There are many documented examples of this phenomenon.¹⁶ In the process of electron capture, each neutron created, absorbed 782KeV to make up the mass difference. When the neutron(s) bond to another nuclei, the nuclear bonding energy is released as a boson(s).

$$(\text{Neutron} + {}^1\text{H} - {}^2\text{H}) \times c^2 = 02.237 \text{ MeV} = 0.358 \text{ Pico-joule}$$

$$(\text{Neutron} + {}^2\text{H} - {}^3\text{H}) \times c^2 = 06.259 \text{ MeV} = 1.003 \text{ Pico-joule}$$

$$(\text{Neutron} + {}^3\text{H} - (\beta^- + \bar{\nu}_e + {}^4\text{He})) \times c^2 = 17 - 20 \text{ MeV} = 2.7-3.2 \text{ Pico-joule}$$

The path of the reaction when run with deuterium is

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

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 energy¹⁷ and because they are electron neutral. The system starts with two neutrons and two protons in the form of two deuterons, and ends in 4He , which has two protons and two neutrons. However, the path to 4He is through the conversion of a deuteron to a dineutron.¹⁸ A system made up of only two neutrons is not bound, though the attraction between them is very nearly enough to make them so.¹⁹ 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 $P \rightarrow D \rightarrow T \rightarrow {}^4H$ however, D is more likely to undergo an electron capture event and T is probably even more likely than D to undergo an electron capture event. If working with protium, this may lead to other isotopes along the valley of stability of nuclei. Funding will be necessary to properly study these phenomena.

2.2 The 4H Beta Decay Path

The first three pieces of information on the decay of 4H that someone is likely to find will, in most cases, stop them from digging further into the National Nuclear Data Center (NNDC). 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 4H at an energy level below 3.53 MeV, it would likely undergo a β^- decay and yield 17 to 20 MeV of energy depending on the mass of 4H . However all the data in the NNDC is collected from high-energy physics experiments. The lowest energy level experiment that produced any indication of 4H is an early sub-decay product of ${}^7Li(\pi, t){}^3H+n$. That is the result of an 8 MeV neutron colliding with 7Li . *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 4H shows the decay mode as n: 100% or as always

undergoing a neutron ejection decay mode.²⁰ Also as a result of the production mechanism, the ⁴H 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 782 KeV to mass in the creation of a neutron) 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 ⁴H undergoing n: %100 neutron ejection decay mode and that ⁴H 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 ⁴H, that is the immediate aftermath (~10⁻²⁵) sec after an 8 MeV collision.

2.3 Data from Energy Levels of Light Nuclei A=4

The following informational data sheet may be 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 click the HTML button:

⁴H Adopted Levels 1992Ti02¹⁹⁹⁸⁰⁷
 Published: 1992 Nuclear Physics.
 Qβ=-23.51×10³ S_n=-2.91×10³ 1997Au0
 11 11 7

Type	Author	History Citation	Cutoff Date
Full evaluation.	H. Kelley, D.R. Tilley	Nuclear Physics A54111	8-Oct-1991
	H.R. Weller and G.M. Hale	(1992)	

The stability of the first excited state of ⁸Li against decay into ⁴He+⁴h (1988Aj01) sets an upper limit for B(⁴h)≤3.53 MeV (see refs in 1992Ti02). This also sets a lower limit to the β- decay energy ⁴h→⁴He of 17.06 MeV. The upper limit of the β- decay energy would be 20.06 MeV, if ⁴h is stable against decay into ³h+n. Estimates for the expected half-life of the β decay: if J^π(⁴h)=0-, 1-, 2-, T_{1/2}≥10 min; if J^π(⁴h)=0+, 1+, T_{1/2}≥0.03 s (see discussion in 1992Ti02). Experimentally there is no evidence for any β- decay of ⁴H, nor has particle stable ⁴h been observed. Evidence for a particle-unstable state of ⁴h has been obtained in ⁷Li(π-,t)³h+n at 8 MeV 3 above the unbound ³h+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 ⁴Li after shifting all the p-³He E(λ) values by the internal Coulomb energy difference ΔE(Coulomb)=-0.86 MeV. The parameters then account well for measurements of the n-³h 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 ⁴Li analysis unambiguously determined the lower 1-

level to be predominantly ³p₁ and the upper one to be mainly ¹p₁; that order is preserved, of course, in the ⁴h 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.

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 the thermal conductivity and the electrical conductivity. In particular, the properties of long-wavelength phonons gives 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 sonar²¹ and ultrasound.²² 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 (time-domain reflectometry).²³

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 duality²⁴). 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 Figure 2. The amplitude of the wave is given by the displacements of the atoms from their equilibrium positions. The wavelength λ is marked.²⁵

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 dimen-

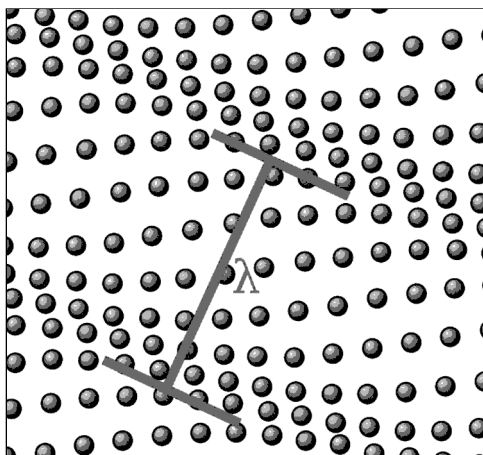


Figure 2. Phonon propagation schematic.

sional 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 scattered in-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 H₂ or D₂ 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 nucleolus 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 the lattice, will be discussed in Section 2.7.

2.5 First or irreducible Brillouin zone

The following definition of “first Brillouin zone” is from http://en.wikipedia.org/wiki/Brillouin_zone. The atoms in direct contact with the first Brillouin zone are what the Quantum Fusion Hypothesis calls the molecule in the next section.

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 called simply 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 in which the reaction is running). This “Hermitian operator”²⁶ 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.²⁷ 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 five terms. 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 repulsions
5. The potential energy arising from Coulombic nuclei-nuclei repulsions—also known as the nuclear repulsion energy.

$$\hat{T}_n = - \sum_i \frac{\hbar^2}{2M_i} \nabla^2(R_i) \quad 1$$

$$\hat{T}_e = - \sum_i \frac{\hbar^2}{2m_e} \nabla^2(r_i) \quad 2$$

$$\hat{U}_{en} = - \sum_i \sum_j \frac{Z_i e^2}{4\pi\epsilon_0 |R_i - r_j|} \quad 3$$

$$\hat{U}_{ee} = \frac{1}{2} \sum_i \sum_{j \neq i} \frac{e^2}{4\pi\epsilon_0 |r_i - r_j|} = \sum_i \sum_{j > i} \frac{e^2}{4\pi\epsilon_0 |r_i - r_j|} \quad 4$$

$$\hat{U}_{nn} = \frac{1}{2} \sum_i \sum_{j \neq i} \frac{Z_i Z_j e^2}{4\pi\epsilon_0 |R_i - R_j|} = \sum_i \sum_{j > i} \frac{Z_i Z_j e^2}{4\pi\epsilon_0 |R_i - R_j|} \quad 5$$

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:

$$\nabla^2(r_i) \equiv \nabla(r_i) \cdot \nabla(r_i) = \frac{\delta^2}{\delta x_i^2} + \frac{\delta^2}{\delta y_i^2} + \frac{\delta^2}{\delta z_i^2}$$

Since the kinetic energy operator is an inner product, it is invariant under rotation of the Cartesian frame with respect to which x_i , y_i , and z_i are expressed.²⁸

2.7 Non-bonding energy

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.

See the following, from http://cmm.info.nih.gov/modeling/guide_documents/molecular_mechanics_document.html:

The non-bonded energy represents the pair-wise sum of the energies of all possible interacting non-bonded atoms i and j (Figure 3). 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 (Figure 4).

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.). (Figure 5)

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 Profusion Energy Inc., 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 are high current pulses through the core of the reactor. The Q pulses cause electromigration, which is the transport of material caused by the movement of the ions in a conductor due to the momentum transfer between conducting electrons and diffusing conductor atoms. 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/mm² in the core material. The control systems currently in operation are capable of producing pulses up to 35A peak 250ns wide.

The next revision control system will both raise the peak and reduce the width of Q pulses, improving their effectiveness and ability to operate in the pressurized reactor vessel. 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. The Q pulse energy is calculated as $\frac{1}{2} CV^2$ Hz. 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 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, and 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.

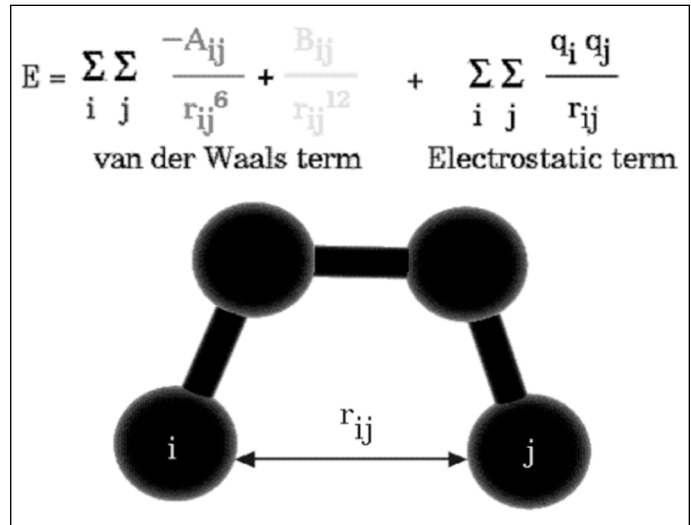


Figure 3. Atoms i and j are non-bonded with separation of r_{ij} used in the equations.

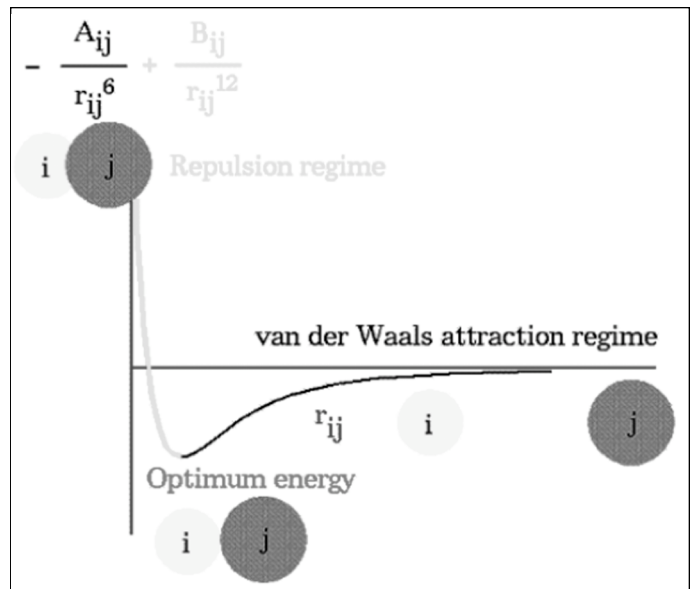


Figure 4. This energy term provides for a smooth transition between attraction/repulsion.

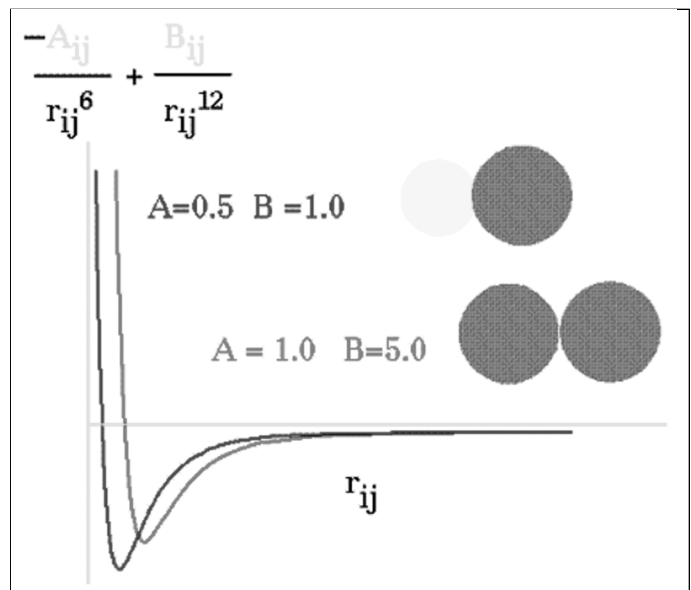


Figure 5. "A" and "B" control the interatomic distance of the potential energy well.

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.

2.10 The Heisenberg Uncertainty Principle

The Heisenberg uncertainty principal states $\Delta p \Delta q \geq h/4\pi$ ²⁹ where Δq is the uncertainty or imprecision (standard deviation) of the position measurement, Δp 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, and \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."³⁰ That is 0.00000017 degrees above absolute zero equal to -273.15°C. This has the effect of making Δp 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 in the system and confinement by electron orbital wave shells. A deuteron is one proton bonded to one neutron. The bonding energy is ~2.2 MeV 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 ~6 MeV 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 D₂O will result in almost 10% protium loading into a Pd cathode.³¹ The reduced mobility of tritium over deuterium over protium is a function of limited physical size of the vacant energy level in the 5S energy band. This energy/physical gap is formed by the interaction of the 4P and 4D orbital probability functions in Palladium. This "box" causes Δq or standard deviation of the position measurement to be severely constrained. This constraint causes Δp 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 Δp . 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.

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 Profusion 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 base molecular Hamiltonian. The grain boundaries and defects reflect phonon energy and the intersection of enough reflections 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 Sections 2.4 through 2.11 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 greater than or equal to 782 KeV has the potential to run the Quantum Fusion process, providing the unit cell has conduction or valance band electrons available for capture. The electron capture event is a natural reduction in energy of this system instantly (sub femto-second) removing 782 KeV from the unit cell or molecule, a significant portion of that energy is the removal of a proton from the bounding "Coulombic box." As the phonon peaks become phonon troughs, the coulomb constraint becomes a vacuum resulting in a low energy neutron—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 Pd.

One of the reasons 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 crosses 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 the great 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 782 KeV, but

when a dineutron fuses with a deuteron 17 to 20 MeV 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 ^4H builds the number of β^- decay events exceeds 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 causes the reaction to release some undesirable high-energy particles 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 constitute 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.³²

The following six concepts work together in driving the electron capture process.

1. Phonons
2. Molecular Hamiltonian
3. Non-bonding energy
4. Heisenberg Uncertainty Principle / confinement energy.
5. Electron orbital probability functions
6. Electromigration

The Electron capture event converts 782 KeV in Hamiltonian energy to mass in the neutron. 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/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 energy/molecular Hamiltonian energy and bosons transferring 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, leading to 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 elec-

trons in a conductor (familiar to electrical engineers) causes the absorption of β^- radiation through direct nucleon interaction. The occasional X ray source has to do with location of the β^- decay events possibly stimulating the X-ray emissions.

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 $\sim 8.15\text{A}/\text{mm}^2$ RMS. For comparison, the wire would start to glow at $\sim 305\text{A}/\text{mm}^2$ RMS equal to 0.6A or 600mA RMS. The wire resistance was $\sim 2\Omega$ indicating that the quantum compression energy (Q or Q pulses) was not a significant source of energy into the system although it was included in the calculation involving the rise of the water temperature. The Q energy calculated as entering the system was based on $\frac{1}{2}CV^2 \cdot \text{Hz}$. 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 not included in the calculation. Using I^2R to calculate the energy in to the core it would appear that Q was responsible for $\sim 0.0005\text{W}$. The calculation actually used was $\frac{1}{2}CV^2 \cdot \text{Hz} = 2.35\text{W}$. This higher value was used to increase my confidence of the effect possibly having commercial value.

As was stated above in Section 2.12, 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 $2\text{-H}_2\text{O}$ 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

Profusion Energy now has pending U.S.³³ and International patent applications prepared and filed by David Slone of Townsend and Townsend and Crew LLP. These include an application describing systems along the lines of what is described above, and applications on specific portions of the drive system.

As of September 3, 2007, the driver system is capable of producing Q pulses up to 35A and is under processor control. The current revision system gives the processor access to loading current, loading voltage, Q voltage source, and a temperature sensor input for feedback on the reaction. This system can reliably raise the temperature of 200ml of water higher than a copper core and/or a resistive heater in the same environment at the same energy input with the lossless Q energy estimate discussed above. In one experiment, 33.7mm of 0.05mm diameter Pd wire was run against an immersion heater. Both beakers had 200mL of 0.5M NaOH solution made with distilled water. The Quantum Fusion reactor had 12W of energy going into the beaker. Next to that beaker was the beaker with the immersion heater. At

12W the reactor leveled off at 61C. The beaker with the immersion heater looked like it would level off at ~55C. The resistive heater was raised to 15W and obtained a temperature of 61C. The two systems were run at this stabilized level for approximately 1 hour from 3:30 to 4:30 p.m. on December 30, 2006.

4.1 Next phase

Work is progressing on the next revision of the control system that will improve Q generation, data collection, calibration, and will add pressure feedback capability to the metrology mix. This next generation system hardware will allow controlled operation in a closed pressurized reactor vessel once appropriate control codes are implemented for this Printed Circuit Board (PCB or Copper). Operation in a closed system is required to obtain calorimetric data representative of conditions used to produce usable energy. With the data collected in this experiment, the path for moving the technology from a laboratory test bed toward a commercially useful product will be clear.

5. TEST PLAN

We expect it to take up to 9 reactor vessel years or 468 weeks/number of reactors to obtain the data and control codes necessary to justify designing a commercial product. Realistically, the existing team members could work with up to six reactors maximum or we would need to hire additional employees.

6. SUMMARY

Profusion Energy Inc. has already constructed a reactor control system capable of producing Quantum Fusion events in an open container, allowing the principles of the Profusion Energy hypothesis to be demonstrated. Profusion Energy currently has an open container demonstration that produces qualitative results but is lacking in quantitative capabilities. The Quantum Fusion process will be characterized in a pressurized boiler, allowing additional intellectual property claims on a commercially viable means of producing industrially useful steam via nuclear fusion. It is expected that it will be possible to “close the loop,” resulting in a device that powers the reactor plus another device.

Profusion Energy has good, repeatable, qualitative results. The company now needs to prove the technology under elevated temperature and pressure conditions, obtain quantitative results, and then move this technology into suitable energy-generating products.

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About the Author

Robert Godes first read about magnetic confinement fusion in 1972 and decided that the combination of control, confinement, exhaust, fuel replenishment, and energy extraction made for a totally impractical source of energy. He started thinking of smaller ideas involving minute quantities of “fuel,” some involving high-energy electrons to create neutrons for accumulation, plate impact of ions. Godes graduated from Ohio Northern University in 1988. His outlook on life and government was probably most impacted by living in Ethiopia for 22 months (1972-1974). Living in a country with people living almost in the Stone Age, digging fields with sharpened sticks with rocks on top, gives you a real appreciation of the things you have—running drinkable water, adequate food, access to electricity, transportation, all the things Westerners take for granted.



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