An Approach to Explaining Cold Fusion

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Abstract – *Cold fusion or Low Energy Nuclear Reaction (LENR) is a process that results in various nuclear reactions involving all isotopes of hydrogen within what appear to be ordinary materials at ordinary temperatures. In general terms, the reactions can be described as fusion when two hydrogen isotopes combine to form a single product nuclei or as transmutation when one or more hydrogen isotope nuclei enter a larger nuclei. As expected, these reactions generate energy but very little radiation is detected, which is unexpected and has been a cause for rejection. Sufficient evidence is now available to justify believing this is a real phenomenon and not the result of error. The challenge is to explain how such an unusual process operates. The approached used in this paper is based on six assumptions and their logical relationship to many observations. Although many details are not quantified, the general characteristics of the LENR process are described. This analysis places severe limits on any proposed explanation.*

Key words*: cold fusion, LENR, CMNS, theory*

I. INTRODUCTION

The LENR process has been proven real[1-3] and is found to be very different from what has been called hot fusion. In hot fusion, the deuterons are forced together with enough applied energy to allow the strong force to take over and complete the fusion process. The resulting energy has to be emitted quickly in a way that conserves momentum, which requires emission of two particles having the required translational energy. These two particles can be either tritium and a proton or He3 and a neutron. He4 is not produced. In contrast, LENR produces only He4 without significant translational energy, which requires the energy be dissipated by a different process. Even when tritium is detected, also without significant translational energy, the expected neutrons are absent (n/T<10-6).

Dozens of explanations are based on ways energy might accumulate in sufficient amount in a chemical lattice to overcome the Coulomb barrier. These processes occasionally involve accumulation of extra electrons between the hydrogen nuclei as another way to hide the barrier. Accumulation of hydrogen nuclei as clusters or Bose Einstein Condensates (BEC), in which the barrier is proposed to be reduced, has also been suggested. These suggestions ignore the severe limitations a chemical lattice imposes on energy accumulation and on changes in electron concentration. Processes do not occur in isolation in a chemical lattice because the relationship between electrons and atoms is fixed by the imposed structure. No proposed theory acknowledges this requirement. This failure makes universal acceptance unlikely.

A different approach is suggested here. Six assumptions are adopted and their logical connection to what has been observed about LENR is used to justify the choice. These assumptions, if correct, lead to several logical consequences from which a general mechanism can be proposed. The process is similar to prospecting for gold. Digging (i.e. creating mathematical models) is useless until the presence of gold at the site is determined by finding some nuggets (i.e. by using the clues Nature provides as a result of experimental study) combined with knowledge of geology (in this case knowledge of basic chemistry and physics). This paper will show where to dig but will not do the digging.

II. DISCUSSION

Assumptions

The first assumption states: LENR does not occur within a chemical lattice, which includes in vacancies of any kind, between atoms where extra atoms might accumulate, or on the surface of such structures. Nevertheless, LENR is known to occur somewhere in a material. Consequently, a location for the process needs to be identified that is consistent with this assumption and can form in all structures used to cause LENR. This region is

called the nuclear active environment (NAE)[4]. For the purpose of this model, the NAE is proposed to consist of cracks, physical voids, or cavities, each having a critical size and shape, which becomes the second Assumption. Such an environment allows mechanisms to operate that are not influenced or limited by the chemical bonds within the lattice or chemical structure. The third assumption states: All reactions identified as LENR occur in the identified NAE, including fusion of all isotopes of hydrogen and transmutation. Because such a unique process is unlikely to occur by more than one mechanism, the fourth assumption states that all LENR reactions result from the same basic mechanism. The fifth assumption states: The mechanism by which fusion and/or transmutation is produced involves a string of alternating hydrogen nuclei and electrons aligned in the crack or void. This string gradually collapses into the final nucleus, including the intervening electron, as energy is lost from the resonance process with emission of photons. For this process to occur, the electron must have a novel relationship to the hydrogen nuclei that is forced on the structure by the walls of the cavity. The sixth assumption involves how this novel relationship can emit coherent photons of a frequency determined by the average mass the of nuclei in the cavity.

Justification for the assumptions:

Assumption #1: LENR does not occur within the chemical lattice, which includes in vacancies of any kind, between atoms where extra atoms might accumulate, or on the surface of such structures.

As explained in the Introduction, conditions required to reduce the Coulomb barrier and dissipate the resulting energy without energetic radiation being produced cannot be created in a chemical lattice. If such changes could occur spontaneously, they would also cause changes in the chemical structure. A lattice, such as the face-centered-cubic structure of PdD, is formed because the energy and concentration of the bonding electrons have certain values. Different values create different structures. Because the structure is created by a periodic arrangement of interconnected atoms, any change in one location is communicated to all other locations, as can be demonstrated by applying local energy or electric fields. Furthermore, as every chemist is taught, a chemical system resists change. If a spontaneous change should take place, it must result from reduction in Gibbs energy. Energy is never observed to accumulate spontaneously, as the Second Law of Thermodynamics makes clear. Therefore, all mechanisms that propose to add energy to atoms or electrons conflict with basic rules governing chemical systems regardless of how this process is described using quantum mechanics. In addition, an assembly of clusters of hydrogen nuclei, whether it is justified by forming a BEC [5], a TSC (tetrahedral symmetric condensate) [6, 7], a Rydberg structure[8] or occur in metal atom vacancies[9] must follow rules imposed by the laws of thermodynamics, which have not been acknowledged in the cited theories.

The limitations created by the chemical structure severely reduce the options available for locating the NAE and identifying the mechanism. The challenge is made even more difficult because the propose NAE must be present under all conditions found to produce LENR. This simple logic leads to Assumption #2.

Assumption #2: The nuclear active environment (NAE) consists of cracks, voids, or cavities having a critical size and shape.

The most likely structure consistent with Assumption #1 would be cracks. Obviously these voids would have to be too small to allow formation of the normal hydrogen molecule, which cannot fuse, yet be large enough to force a novel relationship between the hydrogen nuclei and the intervening electrons that are required to reduce the Coulomb barrier.

These cracks are expected to form as stress is relieved in random locations. Consequently, they would form where stress has accumulated to the necessary amount. Electrolysis is expected to produce stress in PdD as lithium, oxygen, and other impurities accumulate in the surface.[10-12] Once cracks form and stress is relieved, the number of active cracks would remain relatively constant. These expectations are consistent with the observed long delay during electrolysis before LENR starts, the presence of LENR at the surface where these stress-cracks would be expected to form, and a stable limit to the amount power produced once the LENR process starts. Each of the other methods used to cause LENR would have its own cause for crack formation, which can be identified by detailed analysis.

The number of cracks is variable and is determined by a random process. The consequence of this behavior can be seen in Fig. 1. This figure shows the number of times extra power was reported at the power level shown on the X-axis. The amount of extra power is expected to be determined to a large extent by the number of active sites (cracks) present in the material. Consequently, the plot can be interpreted as the number of times a particular number of active sites were created in the sample from which power was produced. The behavior is consistent with a random process, with samples having only a few active sites being created much more often than are samples with a large number of sites. Being a random process, a large probably exists that no active sites would be produced at all, resulting in no excess power. Such nulls occur frequently but are seldom reported. Recent studies using specially treated palladium have shown increased success because more active sites are presumed to be present.[13-15]

Assumption #3: All reactions identified as LENR occur in the identified NAE, including fusion of all isotopes of hydrogen and transmutation.

This assumption is justified primarily by applying Occam's Razor. A process so unique would not be expected to be possible in more than one environment. The fact that LENR occurs in solid inorganic materials and in the chemical structures present in living cells[16, 17] make the properties of the NAE even more unique and potentially even more likely to have a universal structure

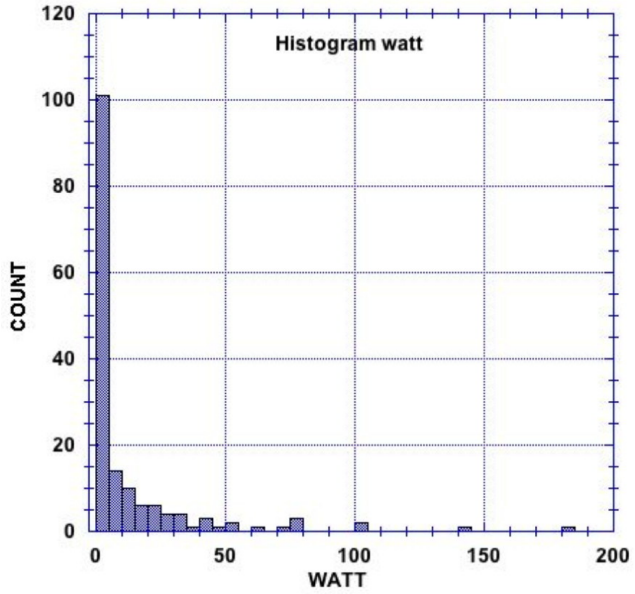

Fig. Histogram of reported power produced from 155 published studies made before 2007 using electrolysis.

Assumption #4 : All LENR reactions result from the same basic mechanism.

A universal NAE would be expected to support only one kind of basic mechanism. The basic nature of this mechanism can be discussed using the formation of tritium. Tritium obviously does not result from the hot fusion reaction of d+d = t+p because the energetic products are not detected and the neutrons resulting from the companion reaction, d+d = n+He^3, are not detected. Consequently, the reaction d+e+p = t is proposed to be the source of tritium. To be consistent with Assumption #4, the He^4, found to be the source of energy when deuterium is used[1], would be produced by the fusion reaction d+e+d. Energy resulting when pure hydrogen is used would result from the reaction p+e+p = d. Once the concentration of tritium has reached a critical level, the reactions d+e+t would result in neutron formation, thereby accounting for the small number of neutrons that are frequently found to be associated with tritium.[2]

These reactions cannot be evaluated using rules based on conventional nuclear processes that result from direct interaction of energetic reactants, such as occurs during hot fusion, when energetic ion bombardment is used, or in the Sun. LENR requires consideration of a novel process. In other words, conventional physics is correct when it is applied to energetic processes but it is not correct when it is applied to LENR. The LENR process is apparently a new phenomenon that must be treated separately.

Assumption #5: The mechanism by which fusion and/or transmutation is produced consists of resonance within a string of alternating hydrogen nuclei and electrons aligned in the crack or void.

The crack is proposed to align alternating hydrogen nuclei and electrons. This string, once formed, can resonate by vibrating along the axis of the crack, which is proposed to emit coherent photons with an energy determined by the mass of nuclei in the string. As a result, the nuclear energy is dissipated over a period of time as emitted photons, most of which are absorbed by the surrounding material and result in the frequently observed heat production.

Piantelli et al.[18] have detected photon radiation using H_2 with Ni and Karabut[19] and Miley et al. [20] have reported such radiation using gas discharge of D_2. Other kinds of radiation have been reported, but their high energy suggests a source similar to hot fusion rather than LENR. [21, 22]

Transmutation is proposed to occur when an atom blocks the end of the crack. This atom is proposed to have the potential to take up one or more hydrogen nuclei (p or d) as they fuse in the crack. These targets for transmutation are the only nuclei that have access to a crack and the mechanism that can release the resulting energy. Because a limited number of such reactions is expected to occur for each active site, the number of transmutation reactions is small.

Assumption #6: The relationship between the intervening electron and the hydrogen nuclei is unique.
Brian Scanlan will justify this assumption in subsequent papers.

Consequence of the assumptions:

Formation of the NAE follows conventional chemical and physical processes. Concentration and temperature gradients cause stress to accumulate in the material, which is relieved by formation of cracks, the number of which partly determines how much power can be produced by a particular sample. Power is also

controlled by how rapidly H or D can diffuse to an active crack. This rate is determined by temperature, concentration gradients, and the nature of the material. Once in the crack, the nuclei fuse very rapidly so that the nuclear reaction is not the rate-limiting step. Consequently, conventional processes can be used to determine how much power can be produced under various conditions once the active sites form. Application of higher temperatures or local energy using lasers or RF will increase power production by increasing the rate at which H or D can reach the active site. Because the hydrogen molecule must be broken into the individual elements before it can enter the material in which the active site is located, any process that increases this fragmentation process will accelerate the LENR reaction. Because these processes operate in series, changes in the one that is rate limiting will have the greater effect on power production.

If H is present alone or with D, tritium is predicted to accumulate in the material as energy is generated. Precautions must be taken to protect against this radioactive and potentially dangerous isotope after the material has produced a large amount of energy.

III. SUMMARY

A special environment (NAE) is proposed necessary for LENR to occur and this environment is located within a solid material but it is not part of the chemical structure. The active structure is proposed to be cracks, voids, or cavities of a special size and shape.

Six assumptions have been made from which conclusions about the mechanism that causes LENR can be logically derived. While the proposed mechanism is consistent with many observations, the obvious conflicts with conventional nuclear physics have not been resolved. Nevertheless, the logic of the process directs attention to a mechanism that is different from the other published processes[23-26] and from any mechanism requiring application of high-energy. The model that results from applying these assumptions allows many behaviors to be predicted and shows how the process will respond to changes in applied conditions.

Once the NAE forms and two or more p or d enter it, a fusion reaction starts. The process releases the energy relatively slowly as photon emission. This emission is fueled by resonance within the structure as it collapses and forms the nuclear product. The photons are emitted with a direction parallel to the axis of the resonance. As a result, laser-like emission produces narrow beams of radiation having a frequency determined in part by the mass of the nuclei in the emitting crack. Under most conditions the frequency is too low for the photons to escape the apparatus.

The electron located between the fusing hydrogen is absorbed into the final product at the end of the reaction. If the final nucleus is unstable, the electron is quickly emitted. Of the unstable products, only tritium decays slowly enough for it to be detected before it converts to the final stable product. The following table shows the possible reactants and expected products. Because absorption and emission of an electron is involved, some energy will be lost as neutrino emission. However, this process is so unlike conventional nuclear reactions that the role of the neutrino is unknown.

TABLE I

Predicted nuclear reactions involving isotopes of hydrogen

Reaction	Energy
$d+d+e=H^4=He^4+e$	Q=23.8 MeV
$d+p+e=T=He^3+e$ (18.6keV)	Q=4.9 MeV (T=tritium=H^3, 12.3 y 1/2 life)
p+p+e=D	Q=1.4 MeV
$d+t+e=H^5= He^4+n+e$	Q=18.1 MeV
$p+t+e=H^4=He^4+e$	Q=20.4 MeV

The model proposed here explains how LENR differs from hot fusion and why the nuclear products are different. The model is being developed in a series of papers [3, 27, 28] with this one being the fourth. Other papers will follow.

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