APPENDIX

For "The Explanation of Low Energy Nuclear Reaction"
Edmund Storms
10/15/14

This Appendix is written in response to questions asked by readers of the printed version. Much of what is explained in the previous chapters is expanded, perhaps in a way that is easier to understand. Although this is written as a stand-alone description, relevant sections in the book are noted where more detail could be found.

Acceptance of LENR is made difficult because an explanation of the reaction requires a marriage between physics, particularly nuclear physics, and chemistry, especially materials science. We all have been taught that the forces holding a chemical structure together have no ability to influence the large forces required to affect nuclei behavior. Cold fusion provides a counter example of this meme. An explanation and universal acceptance requires resolution of this conflict. This book focuses mostly on the chemical aspects of the process, with a discussion of the quantum mechanical implications added at the end of the Appendix.

Overview

The chemical aspect of the process starts with assembly of a novel collection of two or more hydrogen[1] nuclei, the raw material and fuel for the fusion process. This process must be consistent with the known thermochemical properties of the material[2]. Conditions existing in plasma where the nuclei can interact at random without regard to the chemical properties are not present in solid materials. In contrast to plasma, the atoms and electrons in a chemical structure all have a choreographed role they are forced to play. These roles determine how, when, and where a cluster can form. Many theories proposed by physicists fail to consider these roles when they claim clusters of hydrogen nuclei can form within the chemical lattice itself. This claim is based on the early thinking of Preparata and others(*533, 692-694, 696, 700*), and, although it is widely accepted within the field, the concept is widely rejected by conventional science, thereby adding to the difficulty of achieving universal acceptance.

Once a cluster of hydrogen forms, a mechanism must overcome the Coulomb barrier between the nuclei without the need to apply high energy, such as theories based on hot fusion require for fusion to occur. Such a process requires the focus be shifted from the conventional concept of cross-section to instead how the barrier can be significantly lowered[3]. The unique characteristics of this environment and process must be identified before understanding can advance to the next stage.

After these problems of forming an assembly of hydrogen fuel and identifying a mechanism to overcome the Coulomb barrier are solved, another challenge remains. The resulting mass-energy must be dissipated without producing significant energetic radiation. Furthermore, all of these events must operate in perfect collaboration to avoid

---

[1] When the word "hydrogen" is used, it means all isotopes of hydrogen.

[2] The relevant properties of PdD are discussed in Section 2.7.0.

[3] A distinction is made between the conditions present in the crystal lattice, on which the chemical compound is based, and cracks that exists where the lattice has fractured and separated. Both conditions are present in the material but represent two entirely environments.

the hot fusion-type reaction. Explaining one of these events while ignoring the others is a very common and not very useful feature of many proposed theories.

Experimental observations show that only certain rare locations in the material appear to be active. I call these active regions the Nuclear Active Environment (NAE). This name identifies the unique condition that must be present for hydrogen fusion to occur, although the process may not start unless other conditions are also present. For example, the NAE must be present while at the same time hydrogen must be available at the site. All locations in the sample without this combination are inert regardless of the applied conditions. The unlikely and random presence of the required conditions has made the attempted replications very uncertain. Nevertheless, failure to replicate does not negate the claims. In fact, identifying and creating these active sites remains the major problem in generating energy at a useful and reliable rate.

In addition to meeting the above requirements, all LENR theories must be consistent with a collection of observations. These are discussed in Chapter 2 and summarized below.

1. Formation of helium is correlated with energy that corresponds to the MeV/He expected from D-D fusion. (Section 2.2.0)
2. Formation of tritium is possible when using either deuterium containing some protium or natural[4] hydrogen containing some deuterium. Tritium is produced without significant neutron emission or any other energetic radiation. (Section 2.1.0)
3. Significant energetic radiation is absent, but radiation having an energy that only can be produced by a nuclear process is detected. (Section 2.4.0)
4. Extreme difficulty has been experienced in initiating the fusion reaction, with success being improved by experience.
5. Either naturally occuring hydrogen or deuterium can produce significant excess energy.
6. Two kinds of transmutation are observed, one that results in fragmentation of the product nucleus, and one that does not fragment after two or more hydrogen nuclei of H or D are added to a target nucleus. (Section 2.3.0)
7. A total fusion rate in excess of 10^{12} events/sec is occasionally observed to take place somewhere in a material.
8. The nuclear products and radiation produced by hot fusion are not normally observed, although this radiation is detected on rare occasions at very low level.

The nuclear reaction is observed to take place generally at or near the surface of a solid material after it is exposed to any isotope of hydrogen, with most studies using deuterium. This conclusion results from the observed creation of helium and tritium in such material, with the manner of their release into the surrounding environment revealing where the nuclear products were produced. The detection of accompanying radiation is also consistent with a nuclear reaction taking place. These behaviors have been observed on so many occasions, the possibility of their being caused by error is insignificant. As required by science, the consistent patterns of behavior have revealed LENR to be a real phenomenon. Therefore, we are encouraged to explain how this process works, with the goal of making it useful as a source of commercial energy.

---

[4] Natural hydrogen exists in nature and consists of protium mixed with a small amount of deuterium.

Although the discovery process is still very incomplete, a plausible path to understanding is the goal of this book.

Unlike hot fusion, which takes place in plasma, the cold fusion process occurs within a solid created by a highly structured collection of atoms and without input energy being required above ambient conditions. This unique condition places severe restraints on what can be proposed about the process. The rules for the hot fusion process do not apply to cold fusion, although an attempt was made to impose these rules early in the history of the discovery. This conclusion is a serious flaw in the initial approach to evaluating the claims for cold fusion and remains a problem even today.

Search for an explanation must start with the process of creating the assembly of hydrogen nuclei. Once this structure forms, the cluster can initiate fusion by a truly unique process. We must decide how many accepted rules need to be broken and how many new rules need to be created for such a cluster to form. In my search for an explanation, I have avoided breaking any rules and suggest the creation of only a few additional new ones. In other words, I view LENR as being consistent with all we know about chemistry and physics. We only need to accept that something is missing from our understanding of nuclear interaction in order to explain LENR.

Formation of the hydrogen cluster

Most theories of LENR assume the unique location of the NAE is within the chemical structure, typically within the face-centered-cubic (fcc) crystal lattice of PdD. In this case, the NAE is proposed to be vacancies where a deuteron would normally be located or sites where a Pd atom is missing. A defect or error in placement of the metal atoms is also proposed as a location. To understand how atoms might assemble in such vacancies or defects, the mechanism for creation of a chemical structure needs to be understood.

A chemical structure forms spontaneously only when it is more stable in the ambient conditions than any other possible arrangement of atoms. This stability is quantified using the concept of Gibbs energy. When an arrangement is more stable than any other, it releases the required Gibbs energy for its formation to its surroundings. As result, the energy of the surrounding atoms or structures changes to produce an over all increase in Gibbs energy that is subsequently released to the surrounding environment.[5]

For example, solid Pd forms the face-centered-cubic (fcc) structure because this arrangement is more stable than the many other possible combinations of Pd atoms in the ambient conditions normally used. When Pd reacts with deuterium, the d ions occupy positions between the Pd atoms rather than causing a change in structure because this arrangement is the most energetically stable of the many possibilities. For a cluster of D to form in this structure, that cluster has to have a greater Gibbs energy than any other possible arrangement of deuterium atoms. If this were true, and a cluster did have a greater Gibbs energy than its environment, such clusters would be found as a common feature in the PdD fcc structure. In fact, such clusters are not detected even after much search. Some people suggest that the rare clusters are only revealed by their ability to

---

[5] When describing Gibbs energy, some confusion can result because when Gibbs energy is generated by a reaction, its subsequent loss from the system is conventionally given a negative value. To avoid this confusion, generation of Gibbs energy is described here as a positive event, not as a negative event even though the energy is lost from the system.

produce the observed LENR reactions while ignoring the circular logic this claim implies.

On the other hand, such clusters might form in the lattice, not as a stable structure, but as a random event where two or more deuterons might find themselves at the same location for a brief time. Such events can be analyzed using the concept of probability. Because the probability of forming such a structure goes down as the number of members in the group goes up, so that the larger the cluster, the less likely it would form. This basic fact eliminates formation of large clusters by this process.

The probability of creating clusters by any process can be expected to increase as the D/Pd ratio is increased. This means the amount of fusion power should increase as the D/Pd ratio is increased, as is observed. Yet, if this were the only factor, we would expect all PdD having a high composition would support a fusion reaction. That expectation is not realized. Therefore, the rate of formation of clusters is not the only important variable. Furthermore, the number of occasions when two D occupy the same location by random chance has been calculated and not found consistent with the observed fusion rate. Therefore, all theories that require formation of a large cluster within the lattice are eliminated from consideration because they conflict with basic chemical laws. This problem is discussed in detail in Chapter 3.

Since clusters cannot form in the lattice itself, another location needs to be found in the material, but that is external to the lattice. The known and often observed crack structure provides a plausible location. Cracks create an environment between their walls having properties entirely different from those present in the lattice structure. Clusters of hydrogen might assemble in this environment without having to meet the Gibbs energy requirements known to control conditions in the lattice. However, not all cracks are suitable. Large cracks are observed to allow formation of the hydrogen molecule, which is a gas that does not fuse. Is it possible for a very narrow crack to force hydrogen into a new structure that can fuse? Such a new structure is described in Chapter 5 and later in this Appendix. Once a suitable assembly of hydrogen nuclei forms, the next problem involves overcoming the Coulomb barrier.

Mechanism to overcome the Coulomb Barrier

All nuclei repel each other because they each have a positive charge. For two hydrogen nuclei to fuse, the force exerted by this charge must be met with an equal and opposite force. The hot fusion method overcomes this repulsive force by using the kinetic energy acquired by particles at very high temperatures. Bombarding a material with energetic deuterons also can provide this force. In this case, the electrons in the material help reduce the Coulomb barrier so that less force is required to produce the same rate of fusion between the deuterons, especially at low applied energy. The repulsive force can be partially overcome by substituting a muon for the electron in the deuterium molecule, which because of its greater mass, forces the deuterons closer and increases the hot fusion rate without additional kinetic energy being required. In each case, the separation is reduced enough for the strong force to take over and draw the nuclei together. These methods have no relationship to cold fusion because hot fusion is the result, not cold fusion. The nuclear mechanism and the resulting products are different. Failure to accept this fact has resulted in considerable confusion and rejection of cold fusion.

Nevertheless, the barrier must be overcome, either by reducing it and/or by applying sufficient force. Various theories propose different mechanisms, which include shielding, tunneling, electrons at energy levels below the normal Bohr energy, creation of a Bose-Einstein Concentrate (BEC), creation of neutrons, and/or concentration of energy. None of these methods is fully consistent with observed behavior or accepted natural law.

Once the Coulomb barrier is overcome and fusion takes place, we are then faced with explaining how excess mass energy between the reactants and the products is dissipated into the material to appear as heat.

Mechanism to dissipate excess mass-energy

Hot fusion and other conventional nuclear reactions dissipate the resulting mass-energy excess by emitting particles or fragments of the nucleus after its formation. Cold fusion does not do this. In LENR, the final nucleus remains intact and the mass-energy is manifested in a different way. This difference in behavior is one of the major reasons the claim for LENR is rejected and provides another difficulty for an explanation to overcome.

The mass-energy has to be released to produce heat, which is measured and found to be consistent with the expected excess mass-energy change. This release is proposed in various theories to involve phonons[6] and/or photons[7]. In other theories, a single fusion in large cluster is proposed to send all the other deuterons away as in a grand explosion, without the need to produce phonons or photons. However, this method is consistent with observation only when the cluster is very large, perhaps in excess of several thousand deuterons. As explained above, such large clusters would be too rare to explain the observed rate of reaction.

If phonons or photons are involved, they must each have only a fraction of the total mass-energy based on observation. This means a mechanism must distribute the energy into small units over a period of time. In other words, the energy must leak out bit by bit. We are faced with explaining how 23.8 MeV can leak out before helium forms when deuterium is used because otherwise the energy would be released all at once by hot fusion. Use of the concepts involving slow release of mass-energy after the helium nucleus forms only distracts from this problem because helium has no known way to store the energy while it is being slowly released. If such storage were possible, fragmentation of the nucleus would not always occur during hot fusion.

In view of these requirements and limitations, a new model is justified in Chapter 5 and summarized below.

Further justification for a new model based on the Hydroton

Two separate problems have to be solved. First, the unique characteristics of the NAE need to be identified, and second, the fusion mechanism operating inside the NAE that causes the nuclear process must be understood. At the very least, to make useful energy the NAE must be correctly identified and created without fail, because once the NAE is created the fusion process appears to take place spontaneously without additional

---

[6] Phonons describe energy transferred by vibration of atoms and/or electrons, normally associated with temperature of a material - the higher the temperature, the greater the energy of the photons.

[7] Photons describe electromagnetic radiation identified as visible light, X-rays, gamma rays, and radiation used to operate radios and other communication devices. (See Fig. 56)

effort or understanding being required. Nevertheless, additional understanding of the NAE is necessary to improve the reaction rate and reliability.

As discussed above, a suitable assembly of hydrogen nuclei cannot form in the lattice. Where else might it form? Another location might be within the crack structure known to form in most materials. A crack consists of two nearly parallel surfaces with a variety of gap widths. The gap between these surfaces can be as small as several times the lattice parameter or large enough to be clearly visible. If a crack were the location of the NAE, the gap dimension would be important. For example, as long as the distance between the crack walls is similar to the normal gap between Pd atoms in the fcc structure, the D will exist as the typical isolated ions. As the gap gets slightly larger, space is created for the D to bond to each other without interference by the intervening Pd atoms. The nature of this bond would depend on the gap dimension, with a large gap permitting formation of the normal diatomic molecule. A linear hydrogen molecule called a Hydroton is proposed to form when the gap is large enough to allow the hydrogen to move independently of the metal atoms, but too small to allow the molecule to form. Gaps in this critical range are expected to be rare and contribute to the difficulty in initiating LENR.

To fully understand the process, the strong negative charge present on each wall of the crack, which is characteristic of all clean surfaces, must be considered. I propose the strong negative charge within the gap forces the bonding electrons between the hydrogen nuclei out of their normal orbit and into one not occupied by other electrons. As result, a new chemical molecule is created based on the p-level electron structure as result of the normal release of Gibbs energy. Presumably, the Hydroton is a form of metallic hydrogen (Section 5.2.1) such as can be created by application of high pressure. The resulting higher-than-normal electron state also makes it a form of Rydberg matter (Section 2.5.2). Of course, a small amount of chemical energy is released by its formation, but this is overwhelmed by the subsequent release of nuclear energy.

A gap formed between surfaces covered by a monolayer of absorbed material, such as would result from exposure to air, would not allow the Hydroton to form. The absorbed molecules would neutralize the high negative charge on the surface and prevent formation of the Hydroton molecule. This effect precludes gaps formed between powder grains from being active unless the powder is formed in pure hydrogen. Presumably, dirty surfaces can be cleaned by extended treatment, but this process would add difficulty to initiating LENR. Only clean surfaces, such as are formed when cracks are first created, have the potential to be active without additional treatment.

The proposed Hydroton is assembled without violating rules known to apply to chemical structures and it reduces the Coulomb barrier without violating the rules known to limit the amount of energy a chemical lattice can support. Further, it solves the energy dissipation problem by emitting low-energy photons that are converted to heat well away from the active sites where the energy would not destroy the NAE. In addition, the NAE is identified, thereby allowing it to be created on demand. This general description shows where to look and what behavior would be expected when LENR is studied.

How can cracks be formed?

Cracks are formed by stress release. Stress can be created by chemical reactions occurring within a material. For example, reaction of hydrogen with palladium to form

$PdH_{0.9}$ causes the lattice to expand by 12%. This expansion causes cracks to form at sites that are weaker than the surrounding material, generally in the surface region. This weakness is influenced by crystal orientation, local hardness, local impurity content, and rate at which stress is generated. Because cracks form most often between grains, the grain size at the surface becomes an important variable. The shape and size of the sample also play a role, with a powder having fewer tendencies to crack compared to a larger piece of material. A critically small particle is not able to crack at all, which would limit the particle size expected to be useful.

Palladium, being ductile, forms a few large cracks unless the surface is made brittle by deposited impurities. The frequently observed long delay in initiating excess energy using the electrolytic method might result from the surface having been made sufficiently brittle by deposited impurities. These impurities are observed deposited with many local variations on a micron scale and with a concentration that is very difficult to measure and control. As result, the LENR reaction appears to occur by random chance and its rate is not stable. Success requires total control of the gap structure.

The most obvious method is to create the gaps artificially by nano-machining. This method would allow creation of a high concentration of active gaps in a material having an ideal combination of the other required properties. Discovering how to create the NAE at high concentration should be the focus of future research before attempts are made to design a practical energy generator.

Engineering Behavior

Once a mechanism is proposed, its overall behavior needs to be described so that engineering principles can be applied. This step is missing from most proposed theories.

The amount of power produced is expected to be proportional to the number of active cracks available in the material and how rapidly the hydrogen fuel can find and populate them with Hydrotons. The greater the concentration of hydrogen isotopes near the NAE and the higher the temperature at the NAE, the faster hydrogen can find the few active gaps and produce Hydrotons. In other words, the number of generators and the availably of fuel control the engineering behavior, as is true of all energy generators. From an engineering viewpoint, this is a very conventional system once the NAE is identified.

Each method used to initiate the nuclear process has a different problem with delivering fuel to the NAE. The NAE can accept the hydrogen only as ions. These ions normally are present in the surrounding material, but they can also be made available from the surrounding gas. Gas discharge can be used to create the required ions. However, gas discharge is only useful in populating the first surface the ions contact, with very little influence in deeper layers of material. Consequently, the process is not effective when powder is used because the grains of powder below the surface would not experience the consequence of discharge.

If the applied current is too great, the active surface can be steadily removed by sputtering, thereby limiting the rate at which LENR can occur. With enough effort, an ideal current-voltage combination can be identified to add hydrogen without removing the surface faster than the NAE can form. Increased ion energy (as an applied voltage) is important also because the greater the energy, the deeper the ions can penetrate into the chemical structure and the faster the hydrogen can locate the few active gaps in the otherwise inactive material. This description reveals another variable that influences power production. This variable is the rate at which hydrogen isotopes can leave their normal chemical state in the surroundings and enter the material near the site of the NAE. Electrolysis, during which the hydrogen fuel is present as water, influences this process to a different extent than does using gas discharge or gas loading where the fuel is present as a gas molecule. Consequently, the influence of the method on this variable is important and needs to be considered.

Further complicating interpretation is the increased temperature caused by power being applied to the surface by the method used to generate the ions. As result, local temperature at active sites is expected to be greater than the average measured temperature, which alone will increase the rate of the LENR reaction underway in the NAE by an unexpected amount. Consequently, sorting the variables is not an easy task. The lack of a theory able to identify the important variables has hampered this search, a problem that the theory proposed here attempts to solve.

Proposed mechanism for excess mass-energy release

So far, this discussion has described the normal chemical processes preceding fusion. However, the release of energy from the fusion process requires a new mechanism having no relationship to chemistry and to which quantum mechanics can be applied. Because the energy-release mechanism is very fast, it has the least influence on engineering behavior. Furthermore, a detailed understanding of this mechanism is not required to design a useful energy generator. Nevertheless, such understanding allows identification of the expected nuclear products. Because one of the products is tritium, a potentially dangerous isotope of hydrogen, being able to predict its production rate is required. Harmful radiation is normally not detected from LENR reactions, but understanding the conditions that might change this behavior would also be important.

Two sources of photon radiation are proposed to result from the LENR process. The first results because the Hydroton contains positively charged nuclei that experience coherent vibration in an electric field. Such vibration produces electromagnetic radiation (photons) having a frequency equal to the vibration rate. This vibration rate is determined by the mass of each nucleus in the Hydroton, the strength of the bonds holding the structure together, and temperature. This process converts ambient energy (temperature) into a stream of photons. The photons will have a frequency of a particular value and be radiated in a particular direction along the axis of the crack. A detectible signal could be discovered when many active gaps are aligned in the same direction. Of course, only those frequencies able to get out of the apparatus would normally be detected. Application of radiation having a similar frequency would influence the rate of the vibration, such as when laser radiation is applied. This radiation results from a conventional process.

Another source of photons is generated by the unique process of mass conversion into energy. A force diagram shown in Fig. 93 provides a description of the proposed energy release mechanism. This figure shows the force experienced by nuclei as they move toward each other. The rising line represents the repulsive force created by the Coulomb barrier as distance between nuclei is reduced. The upper part of the figure shows the relationship between nuclei in a Hydroton before resonance starts.

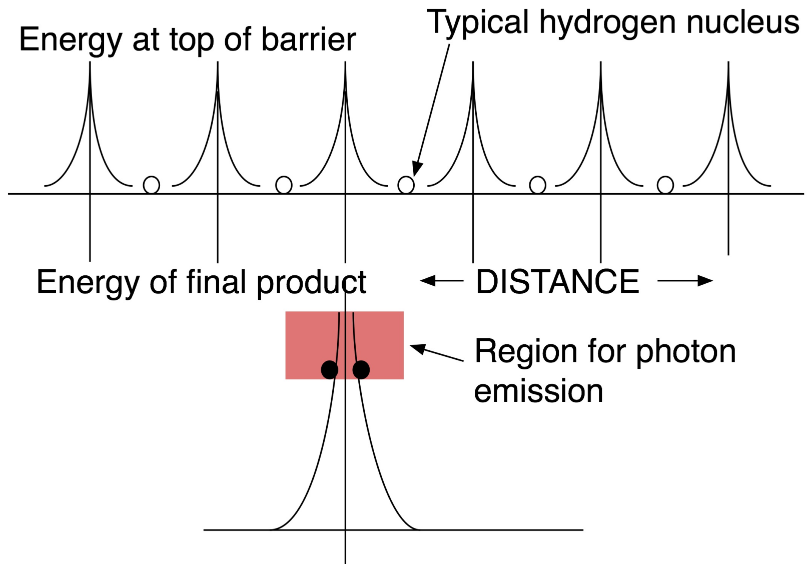

Figure 1. Energy barrier between hydrogen nuclei in the Hydroton. The upper part shows the quiescent position of hydrogen nuclei in a Hydroton. The lower part shows two hydrogen nuclei after resonance has caused them to move up the Coulomb barrier and achieve a distance that allows photon emission. The values are not to scale.

When the separation reaches the value at the top of the barrier, the strong force takes over and quickly causes complete fusion of the hydrogen nuclei. Should this happen without loss of excess mass energy; hot fusion would result. In order for the excess mass energy to be released before complete fusion occurs, as apparently happens during cold fusion, something unusual must take place before the strong force gets involved. I propose a new kind of nuclear interaction is initiated, one that has not been seen before because the required conditions are rarely present in combination. A new process is proposed during which a small amount of excess mass energy is released from each nucleus while at a critical separation. One small quanta of energy is emitted simultaneously from each nucleus at closest approach as a gamma ray (photons), with each emitted in line with the vibration in opposite directions and with opposite spin. The nuclei can be said to "know" that too much mass energy exists in the combined nuclei while at a critical separation before the fusion process is complete. At large separation, the Coulomb force dominates. At small separation, the strong force dominates. I propose at a critical separation, a new interaction occurs that LENR has revealed.

This process is visualized by the lower part of Fig. 93. Here, two typical nuclei in a Hydroton are shown after having moved up the wall until their momentum is expended. If they are able to achieve a separation shown in the red colored region, a process not normally observed takes place. At this separation, the two nuclei find they have too much mass-energy even though they have not completely fused into the final nucleus. While they remain in the red separation region, photons are emitted that carry away part of this excess mass energy. Because the nuclei have not yet fused, the Coulomb force can push them apart. Once the separation has increased, no further photons can be emitted until the process repeats at the next resonance cycle. This periodic approach, followed by photon emission, continues until most excess mass energy has been lost from each hydrogen nucleus. Each cycle adds a little energy to each nucleus as momentum is transferred by the emitted photons. This allows the nucleus to climb higher on the wall at each cycle until the separation is reduced enough for the strong force to complete the fusion process. A normal radioactive decay process that produces gamma emission removes any remaining small amount of excess mass energy in the final nucleus.

Because the bonding electron is located for significant time between the two nuclei, where it reduces the Coulomb barrier, it can be captured in the final nucleus by the fusion process. (See Table 11) As result, when deuterium is used, ^{4}H forms and rapidly decays by weak beta emission to produce the observed ^{4}He. A mixture of H and D produces ^{3}H (tritium), which slowly decays by weak beta emission. A Hydroton containing only H produces ^{2}H (deuterium) that is stable. A mixture of tritium and deuterium is predicted to fuse by the LENR process to produce ^{4}He + a neutron along with an energetic electron. This reaction is proposed to be the source of the very small and variable neutron flux found associated with tritium production.

Although neutrinos are involved in these processes, they are ignored in the description because they play no significant role in determining the detected nuclear products or their energy. These predictions provide a way to test this model by searching for the nuclear products and the accompanying radiation.

This process of photon emission does not normally occur because nuclei are not able to have the critical separation under normal conditions. When extra energy is applied during conventional studies of the fusion process, the nuclei do not spend enough time in the critical region to allow loss of detectable mass energy as photon emission. Instead, the nuclei pass over the barrier with their full excess, which has to be dissipated by fragmentation of the final product. Only application of very high pressure or use of a structure such as the Hydroton allows the critical region to be entered long enough or often enough in the case of the Hydroton for detectable mass energy to be released as photon emission. This model predicts that creation of metallic hydrogen by application of high pressure will result in fusion of the structure and release of energy.

The resonance process can be expected to cause two of the nuclei to fuse before other members of the Hydroton can complete the process. When this happens, resonance would stop and the remaining nuclei that have lost some mass would not be able to complete the fusion process. This result is expected to produce nuclei of hydrogen that are slightly lighter than normal. These nuclei can be described as nuclear isomers that have too little energy rather than too much, as is normally attributed to the isomer condition. Consequently, the occasional LENR reactions taking place over geological time would be expected to produce a few protons and deuterons having less mass than the average.

In summary, the LENR process is proposed to reveal for the first time the existence of a new mechanism for nuclear interaction involving hydrogen. This process has important implications for understanding nuclear interaction, the natural abundance of the elements, and the observed mass of the photon and deuteron. The process also promises to be a source of ideal energy. Acceptance of the explanation proposed here is not required to understand the importance of this new phenomenon to science and technology.

Descriptions based on quantum mechanics.

Several authors have applied quantum mechanics to general situations having a relationship to the Hydroton. The mathematical treatments will not be repeated here because they can be studied in the cited papers. An explicit application of these mathematical formulations to the Hydroton is handicapped by many of the conditions in the Hydroton being unique and unknown. At this stage, these general approaches are only useful to show how quantum mechanics might be applied to the Hydroton as more information is acquired and the focus is finally directed to real materials.

B. Ivlev(*904*) proposes that deuterons can interact if they are aligned such that "the wave function of two deuteron has a formal singularity along the line connecting them. The singularity is smeared out within the thread of the deuteron radius around this line and the state becomes physical." This condition is achieved in the Hydroton structure.

V. I. Vysotskii and M. V. Vysotskii(*905*) address resonance in a condition they describe as follows: "It has been shown that the formation of correlated coherent states at the fast expansion of the well can underlie the mechanism of nuclear reactions at a low energy, e.g., in microcracks developing in the bulk of metal hydrides loaded with hydrogen or deuterium, as well as in a low-pressure plasma in a variable magnetic field in which the motion of ions is similar to a harmonic oscillator with a variable frequency." The Hydroton is proposed to experience such resonance.

V. F. Zelensky(*906*) describes the LENR process as chemonuclear and suggests it can be explained without "going beyond the scope of traditional physics." The term was also applied to apparent fractofusion by A. V. Arzhannikov and G. Ya. Kezerashvili(*907*). Zelensky provides a review of the phenomenon and an explanation based on cluster formation in the lattice, alignment of deuterons, and a process that causes acceleration of a deuteron in order to achieve the required energy to overcome the Coulomb barrier. The structure experiencing fusion is identified as $d^{+}+e+d^{+}$ in which the electron is captured and then emitted with part of the excess energy. Energy is also proposed released as kinetic energy of any deuteron in the cluster that have not yet fused and by "conversion electrons". These features are similar to those present in a Hydroton, although the proposed mechanism is different.

M. Davidson(*908*) explores the idea of variable masses being involved, such as would result when mass-energy is gradually removed from the hydrogen nucleus in the Hydroton before fusion is complete. However, the approach by Davidson is focused on the mass change being the cause of fusion rather than the result.

A. V. Dodonov and V.V. Dodonov(*909*) address the difficulty in calculating tunneling when applied energy is small, such as in the Hydroton. The situation in the Hydroton is even more uncertain because the high negative charge in the gap reduces the Coulomb barrier by an unknown amount.