How the explanation of LENR can be made consistent with observed behaviour and natural laws

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The phenomenon called 'cold fusion' or low energy nuclear reaction has been a challenge to accept and explain. The problem is compounded because an effective explanation must be consistent with the observed behaviour and natural laws. Hundreds of explanations have been published, but none was able to meet this expectation. Consequently, acceptance of the phenomenon by conventional science and application of the energy have been handicapped. The present article summarizes an effort to reduce this problem by identifying a few critical requirements and proposing a mechanism that is consistent with these requirements. This model can also predict many behaviours of importance to science and commercial applications.

Keywords: Cold fusion, hydroton, LENR, theory.

Introduction

LOW energy nuclear reaction (LENR) has attracted many explanations without any of them gaining general agreement. Most are in conflict with each other and/or with various natural laws. As a result, confusion reigns. The first step toward solving this problem requires agreement about some basic facts, rules and assumptions.

The following observed behaviours of LENR are strongly supported and need to be explained.

(1) Formation of helium with the amount of energy corresponding to that expected from D–D fusion.

(2) Formation of tritium when using either deuterium containing some protium or natural hydrogen containing some deuterons. The amount of tritium is found sensitive to the D/H atom ratio.

(3) Absence of significant energetic radiation of any kind.

(4) Extreme difficulty in initiating the fusion reaction.

(5) Significant excess energy produced using natural hydrogen.

(6) Two kinds of transmutation, one that results in fragmentation of the product nucleus and one that does not fragment after hydrogen isotopes are added to a target nucleus.

(7) An occasional fusion rate in excess of 10^{12} events/s.

(8) Absence of the nuclear products and radiation expected to result from hot fusion.

Regardless of the assumed explanation, two or more nuclei must occupy the same small region at the same time before fusion can occur. Assembly of these nuclei must be consistent with the natural laws that apply to a chemical system because this structure must form in a chemical system at a rate and concentration consistent with the observed rate of energy release. Once assembled, a means must be available in the structure to overcome the Coulomb barrier at a significant rate. After the barrier is overcome, a mechanism must be available to dissipate the massive resultant nuclear energy as many low energy units. All parts of this process must take place at roughly the same time and at the same location until the final nuclear product is formed with no residual energy. In addition, the process needs to be compatible with the mechanism that causes the two kinds of transmutation and involves all isotopes of hydrogen. These requirements severely limit the possibilities and encourage some people to believe the process is impossible.

The reality of these observations and requirements is accepted here for the purpose of suggesting a plausible explanation containing as few conflicts with the natural laws as possible. In addition, some novel features of nuclear interaction must be considered if LENR is to be explained, regardless of which proposed explanation is considered. Consequently, finding the most plausible and effective novel feature becomes the challenge to accomplish and accept.

The next question requiring attention is where in the material the fusion reaction takes place. Some theories place the reaction within the bulk material. However, the reaction is now known to take place not in the bulk, but very near the surface when the electrolytic method is used and possibly in all cases. An additional complexity is added because the cathode surface is not pure PdD, which is the assumed host for the fusion process in this case. The process has also been found effective in very thin films and powders where little bulk material is available compared to the amount of surface. Apparently, a feature present only on the surface of a material is important to the process.

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Discussion

Because most information about LENR is based on the behaviour of PdD, this face-centred-cubic compound is used as an example of a process that might take place in any material containing any isotope of hydrogen. To start the fusion process in PdD, a collection of deuterium atoms must assemble in the same place at the same time. Because most theories place this assembly in the crystal lattice, the consequence of this location needs to be explored first.

For such a cluster to form, the rules of chemistry require Gibbs energy be created. This energy can be only created if the assembly is more stable than any other arrangement of D in the lattice. Multiple deuterium atoms are not known to exist in PdD at the same location and their presence would be inconsistent with all that is known about the material. Furthermore, because the assembly process takes place as one nucleus at a time finds the location, the rate of formation will limit the rate at which power can be released by subsequent fusion within the required large structure to small values. To add further difficulty, the amount of energy available in a chemical lattice to initiate fusion is limited by the energy of the bonds holding the atoms in the lattice together, which is far too small to affect a nuclear process. Consequently, a different location must be found for the hydrogen to assemble that is outside the crystal lattice, where these limitations would not apply.

The interior of a crack meets this requirement. Such cracks form by stress relief generally on the surface of a material. In fact, they are observed to form on the surface of a PdD cathode. However, not all cracks will be active. Cracks having too large a gap allow D_2 gas to form, which is well known not to fuse. A crack having too small a gap will not be sufficiently different from the conditions in the lattice to meet the requirement. Consequently, if a crack is the site, it must have a critical gap width in which a collection of hydrogen atoms can form a unique structure able to accomplish what normal D_2 or deuteron ions in the lattice cannot do. This structure is called a Hydroton.

Once this structure forms, its first job would be to reduce the separation between two deuterons enough to start the fusion process. However, if the deuterons are simply brought too close, whether by applying high energy or by use of a muon, the strong force takes over and the fusion process releases excess mass energy as kinetic energy when the resulting nucleus explodes, i.e. hot fusion. This does not happen when LENRs occur. The question is 'Why not'? Apparently, the LENR process causes the nuclei to get close enough for the fusion process to start, but then allows the excess mass energy to leak out slowly so that the normal fragmentation of the resulting ^{4}He does not occur. The great mystery of cold fusion is contained in this process.

To add more complexity, this mechanism is not the only novel feature that needs attention. A mechanism must also overcome the Coulomb barrier without having to apply high energy. The various proposed theories all try to explain this process in different ways, sometimes in ways so complex as to defy understanding. Unfortunately, in the process, they ignore many requirements summarized above and create conflicts with natural laws. To fully explore these conflicts requires a level of detail not possible here. Instead, the reader's attention is directed to a book[1] where a representative collection of proposed theories and their limitations have been described. Rather than examining this large collection in the limited space available here, the discussion is moved directly to a new proposed mechanism that does not have the identified limitations.

The process of finding this explanation starts using the Sherlock Holmes approach. To paraphrase, 'After all the obvious possibilities have been eliminated, what remains must be the truth'. The many attempts at finding an effective explanation have eliminated much of the obvious. Does anything of value remain? One possibility is examined below. Whether this is the truth remains to be determined, but it provides a fresh start down a different path. The path contains some features proposed by other people, but how these features are combined is unique.

Suppose a gap forms (crack) and hydrogen atoms (any isotope of hydrogen) move into the opening. A structure shown in Figure 1 might form if the gap had the proposed critical dimension. At the same time, a strong negative charge forms in the gap as electrons associated with the metal atoms are shifted, on average, into the gap. The electrons associated with the hydrogen atoms in this gap react to this charge by moving to a higher energy state to avoid conflict, perhaps to the conventional p-level. Consequently, these bonding electrons are expected to move freely in the gap between the hydrogen nuclei and the atoms are expected to vibrate in line with the length of the structure. This vibration (resonance) allows adjacent

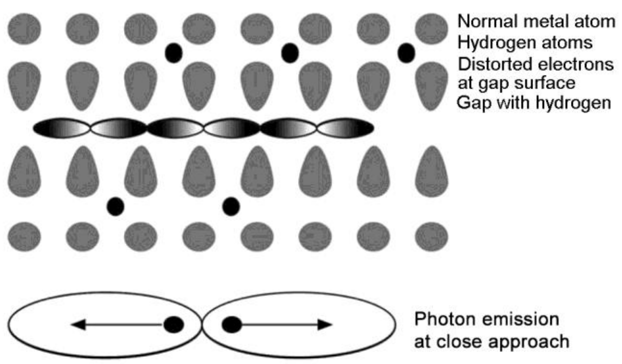

Figure 1. A cartoon of the Hydroton. The Hydroton structure is shown in the active gap with the electron density distribution shown for one part of the resonance cycle. The arrows show emission of photons in opposite directions from adjacent nuclei as they are briefly forced closer by the resonance process[1].

hydrogen nuclei, for a short time, to get closer than is normally possible. So far, this process is completely conventional, but perhaps rare. Now the mystery starts.

As the nuclei resonate, they periodically get closer. This process can be visualized using Figure 2, which shows the force existing between the nuclei. Energy provided by ambient temperature causes the nuclei to move within the energy wells created by the Coulomb force. Because the bonding electrons in this structure and those provided by the metal atoms have reduced the Coulomb force, the nuclei can get closer than is normally the case, but only for a limited time. A novel kind of interaction is proposed to occur when the separation is reduced to a critical value, as shown in the lower part of Figure 2. Once this critical separation is achieved, the nuclei sense that too much mass energy is present for the amount of separation. This unique interaction is the novel feature revealed by the LENR phenomenon. This kind of interaction has not been previously detected because application of high energy causes the separation to pass too quickly through this critical region to allow emission of detectable radiation.

The implications of this idea are significant. For example, for such a process to occur, the nuclei must have a means to communicate besides using the Coulomb force, the strong force, or the weak force. Perhaps, nuclei can interact at a much greater distance than previously thought possible and start to radiate excess mass energy before the strong force gets involved and fusion is complete. Full justification for this is not possible here. Nevertheless, the possibility is worth considering while applying all that is known about the process.

To summarize the proposed idea, if the distance is large, the nuclei repel each other; if the distance is very small, they attract and immediately fuse using the strong

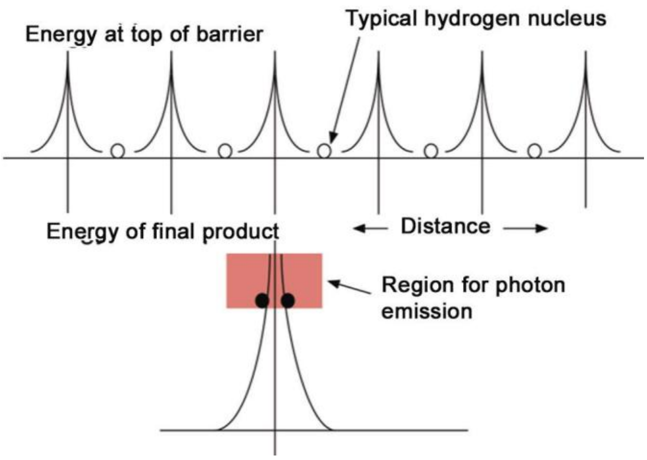

Figure 2. Diagram showing the energy needed to achieve a separation between hydrogen nuclei in a Hydroton. (Top) The quiescent position of hydrogen nuclei in a Hydroton. (Bottom) Two hydrogen nuclei after resonance has caused them to move up the Coulomb barrier and to achieve a distance that allows photon emission. Figures are not to scale[1].

force, and if the distance is just right, they start to anticipate the fusion process but do not yet experience the attraction of the strong force. This 'goldilocks' zone is the unique condition revealed by LENR.

The two arrows in Figure 1 indicate emission of the energy as photons, in opposite direction and with opposite spin from each nucleus. This process repeats as a series of emitted photons gradually drains excess mass energy from the nuclei until they can finally fuse while capturing the intervening electron (see note 1). Emission of each photon transfers some momentum to the emitting nucleus, which allows it to climb higher on the energy barrier and achieve closer separation at each cycle until eventually the strong force completes the fusion process after most excess mass energy has been emitted from the hydrogen nuclei.

If the structure contained only D, the product would be ^{4}H, which is proposed to rapidly decay to form ^{4}He by weak beta emission. If the structure contained D+H, the result would be tritium (^{3}H) that is known to decay slowly to ^{3}He by weak beta emission. Finally, if only H were present, the result would be stable deuterium (^{2}H). In each case, energy would be generated, weak photon emission having a range of energy would result, neutrinos would be involved in the various nuclear reactions involving electrons, and the observed nuclear products and heat energy would be produced.

This process can be described in greater more detail as follows. The active gaps form as a result of stress relief, generally as a result of an uncontrolled and random process. A variable amount of hydrogen assembles in the gap by normal diffusion from the surrounding material to form the Hydroton. This molecular structure forms by release of Gibbs energy as the electrons surrounding the hydrogen nuclei shift to a higher energy and those in the gap wall shift to a lower energy. The highest negative charge resulting from these bonding electrons is found located between the hydrogen nuclei where they are able to partially reduce the Coulomb barrier. The normal vibration caused by ambient temperature causes the nuclei to get close, at which time a photon is emitted. The energy of the photon would not be constant but would depend on how many nuclei are in the Hydroton, the isotopic composition and how much mass energy has been released. Nevertheless, the energy is obviously not sufficient to allow most photons to leave the apparatus where they can be detected. The energy of the photons is sufficient to cause most of them to move well away from the source before their energy is converted to heat in the surrounding material. Consequently, the process does not cause local damage that might stop it, as would result from phonon emission, which is a form of high temperature that would have its greatest value at the source.

The theory further proposes that transmutation cannot occur unless fusion provides the energy to overcome large Coulomb barrier for this process. To acquire this energy, the target nucleus would need to be attached to the Hydroton where it could gain access to the hydrogen and required energy. Which of the two different kinds of transmutation is produced is determined by the isotope of hydrogen present in the Hydroton. The transmutation process is too complex to explain here, requiring a book to justify (see ref. 1, p. 228).

The model can also be applied to understanding the engineering aspects of the problem. Three variables can be identified and used to control the rate of the fusion reaction and hence power production. These are (i) Availability of fuel at the nuclear-active sites. (ii) Number of nuclear-active sites. (iii) Rate of conversion of mass-energy into heat energy by a nuclear process.

The first process is sensitive to the concentration of hydrogen in the surrounding structure and to the rate at which this hydrogen can diffuse from its location in the material to an active gap by normal diffusion. Because the effect increases rapidly as temperature is increased, a runaway condition is possible at high applied temperature, as is observed. The second variable is the hardest to control and generally determines whether the material will be active or not. When too few active gaps are present in the material, the power will be too small to be detected, no matter how much fuel is present. Because these variables interact to control power production, they must be considered when designing a generator and when experimental results are evaluated.

The relative amount of D and H in the material is important. If all else is the same, the amount of power is determined by the isotopic composition of the Hydroton, with 100% D producing much more power than 100% H. Because H produces D by the proposed process and the combination of D and H produces tritium, a power source containing H is expected to generate increasing amounts of tritium. This could be a problem if the presence of this radioactive isotope is not taken into account. For this reason and because more power can be produced, a power generator using pure D is preferred.

A number of predictions can be made to test the concept. For example, when a nucleus on occasion fails to fuse after losing some mass energy, a nuclear isomer having a deficit amount of energy is formed, which is in contrast to the normal nuclear isomer that contains excess energy. This possibility encourages a search for protons and deuterons with slightly less mass than normal. A further prediction results because the Hydroton is similar to a form of metallic hydrogen, which predicts that a fusion reaction would be expected when metallic hydrogen is made by application of high pressure. Resonance in the Hydroton is predicted to generate conventional radiation as a result of charges moving in the electric field created by the crack, which might be detected by suitable detectors. The photons resulting from mass-energy release would have much greater energy than this conventional radiation. The model also predicts that heat energy would result from deuterium formation, not from transmutation as is commonly assumed, when the protium isotope of hydrogen is used.

Conclusion

A collection of requirements is partially summarized as a means to evaluate the proposed explanations. Because none of the present explanations is consistent with all the proposed requirements, a new approach is proposed. The new explanation is consistent with the identified requirements and predicts many behaviours. The phenomenon can be explained without violating any basic natural law provided a single unique kind of nuclear interaction is accepted. At the very least, this explanation provides a new approach to explaining LENR.

Even if this new approach were not accepted, some kind of novel process is required to explain the phenomenon. The question is, 'what kind of novel process can be accepted while remaining consistent with the chosen requirements'? The possibilities are limited. Nevertheless, the common use of those concepts obtained from the hot fusion process is neither needed nor appropriate. Hopefully, this article will encourage a search for an effective explanation to this amazing and potentially useful phenomenon.

Understanding the process at a deeper level than is presently available is essential before the phenomenon can be used as the ideal power source mankind has sought and is required because conventional sources continue to poison the earth.

Note

1. Capture of the intervening electron is required to explain the observed formation of tritium without prior neutron formation, which demonstrates the tritium did not form as result of hot fusion. The only other possible source would be for fusion to occur in the Hydroton between H and D with electron capture. Electron capture is required because otherwise ^3He would form. Helium-3 is not a direct nuclear product, being found only as a product of tritium decay. Furthermore, the close involvement in lowering the Coulomb barrier would make the electron susceptible to being captured by the fusion process.

   If this capture can take place to form tritium, the same process can be assumed to take place when any isotope of hydrogen is caused to fuse in the Hydroton. Of course, neutrino emission would occur, but it would only carry away a small fraction of excess mass energy because very little energy remains when neutrinos are emitted during the fusion process, with most energy having been removed by previous photon emission. While this process cannot be justified using conventional cross-section concepts, the observed behaviour and logic encourage consideration of such a process. See www.LENRexplained.com for more details.

1. Storms, E. K., *The Explanation of Low Energy Nuclear Reaction*, Infinite Energy Press, Concord, NH, 2014, p. 365; www.LENRexplained.com

List of 909 references compiled by Edmund Storms