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Dear colleagues,

I have attached a paper that is the basis for my talks at ICCF-16 and I would like to start a discussion about the conclusions I have made. Some of these conclusions are accepted by other people while others are new and potentially controversial. All of the conclusion can be supported by observation and are not ad hoc. The basic conclusions are as follows:

1. The major nuclear reaction and the source of most energy results from fusion between two deuterons.
2. Tritium results from fusion between a D and H.
3. Both fusion reactions involve the same NAE, the same mechanism, and the same absence of detectable energetic emission.
4. Both fusion reactions involve an electron that gets sucked into the final nucleus, producing tritium when D-H fuse, which decays slowly to 3He, and produces 4H when D-D fusion occurs, which decays to 4He too rapidly to be measured. Consequently, only the formation of tritium reveals the basic process.
5. Neutrons are not part of cold fusion, neither as a reactant nor as a product of a reaction. When detected, they result from rare and local intense sources of energy that produce variations of hot fusion.
6. Transmutation and fusion both involve clusters of D and/or H.
7. The clusters are formed by a novel type of bond at special locations (NAE) in certain materials.
8. Cold fusion does not involve the Pd lattice in any way. The Pd only provides D ions that are needed to make the clusters. Nanoparticle size simply makes more D+ available at a faster rate. Other elements able to split the D2 bond will work as well.
9. Transmutation occurs only when the target atom is present as an isolated atom and not in a regular lattice. Consequently, transmutation during electrolysis involve Pd and Pt that have been deposited on the surface as isolated atoms.
10. Certain inorganic materials and organic proteins both have the ability to produce the active clusters that can support transmutation.

I'm proposing that previous attempts at explaining CF have been looking in wrong locations and are proposing the wrong mechanisms. As a result, many ad hoc assumptions have been required and the results are useless in finding material in which the effect can be amplified. Perhaps some of these conclusions can encourage attention being paid to other possibilities.

Ed

What is real about cold fusion and what explanations are plausible?

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Abstract. Experimental observations are now available to allow rational theories and models about the cold fusion effect to be suggested and tested. This paper summarizes some of this information, uses it to draw logical inferences about the requirements a plausible theory must satisfy, and suggests a plausible mechanism based on these requirements.

1 Introduction

Before examining the known behavior of what is conventionally called cold fusion, the widespread rejection of the claims as describing a real phenomenon must be examined and understood. All new ideas are initially rejected for three basic reasons. The claim is logically false based on objective observation (Rational), the application threatens the self-interest of an individual or group (Political), or the brain of the individual is not designed to accept any new idea (Psychological). While we all attempt to use rational arguments, all too often the other two control the debate. Consequently, we need to take this possibility into account when evaluating our own or as well as someone else's approach. In the case of cold fusion, many people now reject this extremely important discovery for very irrational reasons. The important question is: Why? I leave this as an open question I hope the reader will explore in his/her own mind as this paper is read.

Normally, science bases acceptance of a claim on the quality and quantity of observation and then asks how the observations can be explained. In contrast, many skeptics insist that the mechanism (theory) be found before they will accept the reality. Or as is occasionally expressed; the fact that cold fusion is in conflict with present theory is a reason to reject the claim.[1] By any standard, this is a distortion of the scientific method. So, let's first define exactly what is being rejected. The claim is made that various nuclear reactions, including fusion, can be produced in a special solid environment at modest temperature, in sharp contrast to the expected need to use very high energy to cause significant fusion in plasma (hot-fusion). In addition, this process produces very little radiation in contrast to what is expected from conventional nuclear reactions. Nevertheless, significant heat is detected along with various nuclear products. Acceptance of such a claim requires the reality be tested by many observations that show reproducible behavior, which now has been achieved on numerous occasions. Only then is a theory possible. Unfortunately, explaining how cold fusion works has been a serious challenge. Failure to fully meet this challenge by the scientific profession has been a major handicap to further development and acceptance. This paper seeks to accelerate this process by focusing attention on the important behaviors and requirements a theory must address.

The term “cold fusion” is used here to identify the full range of anomalous behaviors because this designation is now identified with the process in most people’s mind even though it is not completely accurate. The more accurate term ‘Condensed Matter Nuclear Science (CMNS)’ is now used in many publications.

A mathematical analysis is not used in this paper because mathematics is only a tool to compare and extrapolate assumptions. If the assumptions are wrong, the equations have no value. In addition, internal mathematical consistency between various assumptions does not demonstrate that these assumptions are correct. Instead, proposed assumptions will be examined independent of any mathematical consequence. Other people can apply mathematics to those assumptions found valid if they wish.

Hundreds of proposed attempts to explain the effect have been partially described in several reviews[2-5]. To start an evaluation process, a basic question must be answered. How many different mechanisms operate or is just one mechanism causing the different nuclear products and paths? Obviously, all of the different methods would have to produce the same special environment that is required for this mechanism to operate. Just how the environment influences the mechanism to produce the different nuclear reactions is another important issue. The problem is further complicated because apparently both protium (H) and deuterium (D) are able to participate in some of the observed nuclear reactions. Only the involvement of deuterium will be addressed in this paper.

In addition to being consistent with a wide range of observations, a theory must fit the accepted understanding of how materials are known to behave under conditions existing during successful cold fusion studies. After all, this is basically a materials science problem using materials for which a great deal of knowledge already exists. Proposing conditions unique to a theory but never observed in normal material when their presence should be detected is not useful. Also, the mechanism must be clearly related to variables that could be used to change the special chemical-physical environment. Otherwise, we would have no clue, based on the model, about how to modify the environment to enhance the effect.

The first requirement is to list those observations that can be accepted as being clearly related to a nuclear process, hence deserve to be explained. Because the literature describing these observations is so large and has been summarized in other publications [2], only the basic conclusions will be examined here. This examination requires several potential errors be considered. Clearly, chemical processes can produce some excess energy. Therefore, before apparent excess energy is accepted as resulting from a nuclear source, it must be correlated with a nuclear product, such as tritium, helium, or radiation. The magnitude of the measured power and resulting energy can be used as secondary support for a non-chemical process, but only if the accuracy and magnitude of measured power is high. On the other hand, nuclear products are occasionally detected without measurable energy, such as various kinds of radiation and small amounts of tritium. These must result from an anomalous nuclear process even though the amount of energy is too small to detect. Measurements of both heat and nuclear products have been made so accurately on so many occasions, we no longer must rely on poorly done and incomplete studies. Consequently, as much as possible, this paper is based on work meeting these requirements.

The argument that failed studies need to be considered as a balance to success is invalid. The observations are not random, but are clearly related to conditions present during the studies. Failure results when these conditions have not been created either by accident or design. Until all of the required conditions are known and applied, success will continue to be difficult to achieve every time an attempt is made. Some people have a higher rate of success because they have the knowledge and skill to insure the required conditions are present more often than not. The challenge now is to discover all of the unique conditions required to initiate such nuclear processes and teach these to all who wish to study the process.

2 What observations can be accepted as real?

The choice depends greatly on individual opinion and personal knowledge about what has been published. The observations on which conclusions in this paper are based can be readily found on the internet (www.LENR-CANR.org, and http://www.iscmns.org/CMNS/publications.htm) and in published literature, consisting of several thousand papers. Listed below are the major reasons, based on this work, for believing the phenomenon is real.

1. A large number of successful replications and confirmations.
1. The high quality of measurement.
1. Large magnitude of observed effects.
1. Correlation between heat and helium production.
1. Unambiguous nuclear products produced.
1. The effects can be initiated different ways using a variety of materials and methods.
1. All plausible artifacts have been examined and none provide a prosaic explanation for all observations
1. Active programs in eight countries have produced several thousand publications, many in peer-reviewed journals. The number of supporting papers is increasing.

The effect can be made to occur using a variety of methods and the process has several reaction products, depending on the conditions. These facts add support to the reality because plausible error cannot be used to explain similar results using different methods or account for a variety of anomalous products clearly related to similar conditions.

3 What are the reaction products?

The first and most apparent anomalous product is heat production at levels defying easy explanation. Initially, this power was observed near room temperature during early electrolytic studies, making it unattractive as a practical source of energy. The gas-loading method has raised this temperature limit. Increased temperature and other applied sources of energy appear to increase heat production, which give encouragement for still higher temperatures being available as the process is better understood.

The only nuclear product that has been correlated with heat production is formation of helium-4[6] with a MeV/^{4}He ratio close to that resulting from D-D fusion.

The other nuclear products, although clearly detected, occur at rates much too small to produce observable power. In all cases, energetic radiation is largely absent. This feature distinguishes this process from the behavior of normal nuclear reactions. In addition, production of radioactive isotopes, except tritium, very seldom occurs. Apparently, all reaction paths continue to completion until a stable nuclei having the lowest energy is reached, with this one exception.

The rate of each path, when it occurs at all, has a broad range of values depending on conditions. For example, the rate of anomalous power production has been observed between a few mW to over 100 watts, depending on the amount of active material in the sample. Because the gross rate of the nuclear process can have such a wide range in any particular experiment, a correlation to the amount of radiation is difficult to evaluate from present data because suitable detectors are frequently absent. Also, comparing a calculated reaction rate to a value obtained from the gross measurement cannot be used to support a proposed theory. The local reaction rate will be much greater than the measured average. The estimated rates of the various paths are summarized in the following list.

1. Anomalous power (~0.001 -~100 w)
1. Helium (10^{10}-10^{14} events/sec)
1. Tritium (10^{6}-10^{9} events/sec, <=10^{16} measured atoms)
1. Transmutation (~10^{8} events/sec, many elements frequently followed by fission of the product.)
5. Radiation (neutrons [n/T=<10^{-6}], gamma, X-ray, charged particles [α, d, p], and strange) (<10 events/sec)
6. Radioactive elements besides tritium (very rare)

4 What are the methods?

The electrolytic method, using an electrolyte consisting of D_2O+LiOD and a palladium cathode, provided the first evidence for the possibility of an anomalous source of energy[7]. This method remains the one most studied and for which frequent success is reported.[8] The gas-loading method involves simply exposing a special material to D_2 gas, whereupon heat and helium are produced. This method is being currently explored and may provide useful energy and a platform to study the mechanism.

Sonic fusion uses MHz sonic waves applied to D_2O to cause nuclear reactions where the generated bubbles impact on a metal surface. This is different from sonoluminescence where fusion is sought within the bubbles.[9]

Plasma electrolysis uses electric discharge in a liquid, forming plasma, to generate extra energy and transmutation products.

Proton diffusion occurs when a voltage is applied to certain oxides causing diffusion of deuterons and generation of extra energy.

The biological method gives great opportunity for skepticism even though very good work has been published using single-cell organisms. If true, the implications of this claim go far beyond the focus on power production.

The most prominent investigator for each method is noted in the following list to help the reader start a more detailed search. Many other people have made significant contributions as described in the various ICCF conference proceedings (www.LENR.org) and in JCMNS(http://www.iscmns.org/CMNS/publications.htm). These sources of information contain many studies not available elsewhere because access to publication in the conventional journals has been largely denied.

1. Electrolytic - M. Fleischmann, S. Pons[10, 11]
2. Gas-loading - Y. Arata[12, 13], Y. Iwamura[14], L. Case[15]
3. Gas-discharge - A. Karabut[16, 17], T. Claytor[18]
4. Sonic fusion - R. Stringham[19]
5. Plasma electrolysis- T. Mizuno[20], J. Bockris[21]
6. Proton diffusion - T. Mizuno[22]
7. Biological – L. Kervran[23], V. Vysotskii[24, 25]

5 How are these products and conditions related?

Power and helium production are clearly related because they give an energy/helium ratio of 25±5 MeV/He[2, 6], which is close to the expected value for D+D fusion (23.8 MeV/He). This value is greater than any other plausible source of heat and helium, which eliminates all other proposed reactions as the source of heat. Therefore, a plausible theory must address this reaction, explain the high rate, describe how the mechanism fits the conditions unique to each method, and explain why very little energetic radiation is detected. While each method has different gross conditions in which helium and heat are produced, each must have at least one special condition in common, called the Nuclear-Active-Environment (NAE). This term describes the unique condition required to initiate all nuclear reactions wherever they occur. For example, plasma can be the NAE for hot fusion but not for cold fusion, while a solid lattice can be the NAE for both hot and cold fusion, with the amount of applied energy determining which type of reaction occurs and the rate. In this case, the hot fusion process is much less sensitive to the nature of the solid compared to the cold fusion process.

Tritium production has the next most active rate, with values at least 10^4 less than helium production. Tritium production seems to be encouraged by the presence of light hydrogen while this isotope is a poison for the helium reaction. Consequently, both tritium and helium production would be expected to seldom occur at the same time, as is observed. Although the NAE may be similar for these two products and involve the same basic mechanism, the resulting products are different because the reactants are different. Perhaps, tritium results from H-D fusion within the same type of cluster that supports D-D fusion, but occasionally the process traps an electron with tritium being formed instead of ^{3}He. A model needs to explain why this nuclear product can form with residual energy when all other reactions appear to seek the lowest, and therefore nonradioactive, energy state.

Transmutation has a rate similar to tritium production and involves clusters of at least six deuterons[14]. Like helium and tritium production, no evidence for significant energetic radiation has been found, which suggests the mechanism for dissipating the energy is similar to that operating when helium and tritium are formed. This conclusion severely limits the possibilities that can be used to describe each reaction. Many transmuted nuclei apparently fission into two nearly equal parts,[26-28] also without producing detectable radiation.

Neutrons are normally associated with fusion, based on the NAE for hot fusion. Nevertheless, very few neutrons are detected during cold fusion. Even when tritium is produced, the neutron production rate is at least 10^6 less, rather than being equal to the tritium production rate as is the case during hot fusion. Because the rate is so small, the relationship to helium production is not clear. Indeed, neutrons may have no relationship at all to cold fusion, neither as a product nor a reactant. This conclusion is examined in more detail below.

All of the active nuclear reactions, i.e. helium, tritium and transmutation, produce energy and only one clearly identified nuclear product. To conserve momentum, at least two nuclear products are needed to carry away energy-momentum from a nuclear reaction. In addition, nuclear energy is normally so great that it generates many secondary radiations, such as gamma- or X-rays. Although these would be easily detected, they are very rare when any of the observed nuclear products are produced. Therefore, the cold fusion mechanism must couple the energy to many particles residing in the environment near the event so that each particle has too little energy to produce secondary reactions[29]. This coupling mechanism must be very fast to avoid the equally difficult problem of explaining how the generated energy is stored while it is slowly released. Therefore, a theory is useless unless it can show how both the initiation and the release-of-energy processes can occur at the same time without producing detectable radiation. This requirement alone invalidates most proposed theories.

6 What is the nature of the nuclear-active-environment (NAE)?

The nuclear reactions apparently occur near or on the surface of materials and only in the rare locations where the NAE is present. If the reaction were not near the surface, more helium and tritium[30] would be retained by the palladium than observed and the transmutation products[31-33] found concentrated in certain spots would be hidden by intervening material. Obviously these locations have properties different from the rest of the material, which is inert. The challenge is to identify these properties so that more can be created on purpose. Unfortunately, excessive focus has been directed to pure palladium as the active material, which is a distraction because many observations show that the material located on the surface of a palladium cathode where the reactions occur is not pure palladium[34-40]. The potentially active material on a electrolyzed cathode is apparently a complex mixture of at least Li, Si, B, Pt, Pd, D, H, and O. A complex chemical-physical mixture is expected to exist on all materials that are used to produce cold fusion. Which of these elements and their chemical-physical form is important to form the NAE is not known. However, the presence of oxygen and deuterium seems to be common to all materials associated with cold fusion.

The following properties of the NAE have been suggested as single conditions or in combination:

1. A perfect lattice that can support a resonance process.
2. A small lattice, i.e. nano-particles, that have high surface energy or a size that can support a resonance process.
3. A lattice that can contain groups of deuterons as Bose-Einstein condensate (BEC).
4. A lattice that can support a particle-wave transition.
5. A lattice that can transfer small increments of momentum as phonons.
6. A lattice that can generate deuteron clusters.
7. A lattice that can generate electron clusters.

8. A lattice that allows electrons to move so as to offset the Coulomb barrier.
9. A lattice in which electrons can gain enough energy to produce neutrons or dineutrons.
10. A lattice that contains stabilized neutrons or polyneutrons.
11. A lattice that can generate sufficient local field to offset the Coulomb barrier.
12. A lattice that contains magnetic monopoles.

Mechanisms to concentrate energy in the electron structure of the lattice are frequently suggested. Unfortunately, this ignores the role played by each electron, which has energy consistent with this role. If the energy of bonding electrons is changed, the bonds will be altered, thereby absorbing this energy and changing the relationship between the atoms. Even additional energy added to conduction electrons is quickly communicated to the lattice except in superconductors. Consequently, a mechanism proposing to increase the energy of electrons would certainly produce observed changes in chemical-physical behavior long before conditions reached a level required to initiate a nuclear reaction. In other words, ignoring the role of chemistry and the expected easily observed changes in material properties is not useful.

Furthermore, if this process of energy concentration is spontaneous and exceeds what can be achieved by random variations, it violates the Second Law of Thermodynamics. Nature resists spontaneous concentration of energy in any form beyond a certain level regardless of its source. Therefore, a theory making such a claim must show how this widely observed behavior is violated only in the case of cold fusion. Also, why, if increased local energy is available, does the resulting reaction not more closely act like hot fusion, which is observed when this energy is applied on purpose using ion or electron bombardment? In this case, the reaction products are emitted with the expected high energy, in contrast to the low-energy emissions characteristic of cold fusion.

As cold fusion demonstrates, the NAE is very important in determining the path and rate, and in providing a novel energy dissipation process at energy less than a few eV. Ion bombardment studies show that once local energy exceeds a few keV, the fusion paths follow those of hot fusion even in a solid lattice[41-43]. The energy at which a transition occurs between the cold- and hot- fusion mechanisms is not known. Once the hot-fusion process has been triggered, the NAE is important in determining the reaction rate while applied energy is small but becomes less important as applied energy is increased. The reactions become typical of hot fusion in plasma at energy above about 10 keV. The energy at which the tritium/neutron ratio changes from that typical of hot fusion to a value typical of cold fusion is not known. Possibility, occasional local high energy in a sample being subjected conditions used to initiate cold fusion might produce the few observed neutrons, which have no relationship to tritium production.

All attempts at a useful theory are frustrated by major conflicts with present understanding of nuclear and material behavior, as the few examples above show. Clearly, something important is missing from this understanding. The conventional belief that chemical and nuclear processes never interact is clearly wrong. Therefore, a successful theory must focus on the unique nature of the NAE rather than simply describing how a nuclear process might be initiated in a "normal" lattice. A novel chemical bond involving hydrogen might be required, as has been proposed to exist in the

Rydberg molecule [44-46]. Discovery of this new atomic structure has opened the door to a possible explanation for cold fusion based on a cluster of deuterons having nuclear dimensions. This possibility needs to be given more attention.

7 Role of clusters

The extensive studies by Iwamura et al. at Mitsubishi Heavy Industries (Japan) [14, 47-49] has revealed the role of clusters of deuterons in causing transmutation reactions. Clusters up to at least 6 deuterons are apparently created where CaO and Pd are in contact and these are able to diffuse through palladium without being involved in a nuclear reaction. When they reach isolated nuclei that have been deposited on the surface, they react to form other elements. In this case, no subsequent fission of the transmuted nuclei is reported. The nature of the transmutation products observed by Miley et al.[50, 51] also suggests involvement of clusters in producing transmutation.

While evidence for cluster involvement in helium and tritium formation has not been obtained, acceptance of such a role is a reasonable assumption. For a cluster to produce helium and tritium, it would have to form the respective fusion product while the resulting energy is dissipated in a manner that does not produce secondary radiation. This release might result as the remaining fragments of the very large clusters carry the energy or by slow release of photons or phonons from the assembly. If this is the mechanism involved in all cold fusion reactions, finding how such clusters are made and where in the sample they form become important challenges.

8 Role of neutrons

Several people have proposed neutrons are either present in the lattice as a stable form or created from protons and electrons. Once released or created, these neutrons allow observed reactions to take place without a Coulomb barrier being involved. Unfortunately, such proposals have several very basic problems. If neutrons were hidden in a lattice as a stable structure, their presence should be revealed when the material is vaporized. The stable neutron clusters would be detectable either as components in the vapor or as they are increasingly concentrated in the residue. In addition, their presence would change sample density in uncontrolled ways as their concentration changed during chemical or physical processes. None of these expectations has been observed.

If this stable structure decomposed, allowing the component neutrons to react, several other behaviors would be expected. For example, a few of these neutrons should escape and be detected and some of the neutrons should produce radioactive isotopes. The few neutrons that are occasionally detected have energy typical of the hot fusion reaction involving D+D that produces 2.45 MeV, and with a few having energy between 3-7 MeV.[52, 53] Recent use of a CR-39 detector while Pd is electrodeposited from D_2O+LiCl gave evidence for >12 MeV neutrons[54] that perhaps resulted from the T+p, T+d, or T+Li^7 reactions.[55] Such reactions require the tritium (T) to be produced initially with high energy typical of hot fusion. If this is the source of neutrons, the mechanism clearly is not the same as what causes cold fusion. In all cases, the flux is at most a few neutrons/minute compared to 10^{12} helium/sec when 1 watt is generated by the major cold fusion reaction. Clearly, neutron emission results from a very minor reaction.

Furthermore, to make a neutron from a proton and electron requires localization of at least 0.78 MeV of energy. This is hard to justify in a material exposed to ambient conditions. In addition, helium production resulting from neutron involvements cannot generate the observed amount of energy/He and the observed collection of transmutation isotopes is inconsistent with this type of reaction.

Therefore, the observations are inconsistent with neutrons being involved in cold fusion either as a reactant or as a reaction product. The few neutrons that are observed can be proposed to result from very rare local high-energy reactions resulting perhaps from the conventional hot fusion process.

9 What needs to be explained?

Several behaviors associated with cold fusion are now sufficiently well demonstrated for them to be included in any theory. Granted, some of the observations have more experimental support than others. Nevertheless, simply selecting a few behaviors that happen to fit a proposed theory is no longer useful or necessary. When most of the behaviors listed below are considered, present theories are too incomplete to be useful. This failure has been a major handicap to further development of the phenomenon. The major behaviors requiring explanation are:

1. Helium is the main product without significant radiation.
2. The energy/helium relationship is characteristic of D-D fusion.
3. The mechanism that supports this reaction is enhanced by applied energy.
4. Tritium is apparently produced without neutrons or any detectable radiation.
5. Clusters are involved when transmutation is produced.
6. Transmutation is frequently followed by fission of the resulting heavy nuclei.
7. The reactions occur only in rare, isolated regions on or near the surface.
8. The active sites are not pure palladium and may involve other metals and elements as well.
9. Nanoparticles may be required.
10. Light hydrogen may be a poison for the helium-producing reaction involving deuterium but may initiate other reactions without deuterium being involved.
11. Neutron emission is very rare.
12. Energetic radiation is rare.
13. Radioactive products are rare.
14. The NAE has features that appear to be present in both inorganic lattices and organic protein. The relationship between the NAE and the nuclear process needs to be described.

A useful theory must show a logical relationship between all of these observations without an excessive number of ad hoc assumptions being used.

10 Characteristics of a plausible mechanism.

The following assumptions are made in describing a proposed mechanism for the cold fusion process as an example of a possible mechanism.

1. All nuclear reactions typical of cold fusion involve clusters as the initiator. These clusters are created by a novel chemical bond between the deuterons and/or

protons that allows a much smaller bond distance than produced by normal bonding.

2. These clusters are made at the interface of any metal that is able to split the D_2 molecule into ions and an oxide in which the oxygen atom has energy levels required to form the bonds in the cluster.
3. The number of clusters of active size determines the rate of the nuclear reactions.
4. The rate of cluster formation increases as temperature is increased. The total area of the interface determines the amount of active material. Consequently, the smaller the size of the metal, the larger is the area of the active interface. The D_2 pressure determines, in part, the amount of D ion available to form a cluster. The nature of the oxide determines the ability of the clusters to form and grow in size.
5. Only oxides that cannot be reduced completely to the metal by D_2 are active. This limits the kinds of oxides of importance, their range of temperature over which they can function, and the activity of D_2 to which they can be exposed.
6. The cluster has the ability to partially hide the Coulomb charge of its members and the ability to dissipate the resulting energy as the reacting clusters are destroyed.[56] In this case, energy is communicated to so many particles that each has too little energy to produce significant detectable emissions or the energy is released in packets (photons or phonons) having too little energy to be detected.
7. The cluster can contain either H or D. If it contains mostly D, the major reaction is D-D fusion. If the cluster contains mostly H, tritium is the major product. Regardless of the H/D ratio, the cluster can react with certain nuclei, depending on how they are situated in the NAE, to cause transmutation.

While this mechanism is not quantitative, it is consistent with all observations and requirements as outlined above. The next step is to understand how the clusters form and their bonding characteristics that give them the unique ability to initiate a nuclear reaction. This mechanism is suggested as an example of where to look for a useful explanation.

11 Summary

The basic characteristic of the cold fusion process is its absence of significant energetic radiation even when a very large nuclear reaction rate is present. This conflict with expectation is one of the main supports for skepticism and a major challenge to theory. Therefore, a plausible theory must take this behavior into account in a very explicit way. This behavior must be coupled to the observed involvement of clusters and to unusual atomic structures (NAE), not to a perfect lattice of palladium. The theory must also apply to helium, tritium, and transmutation production even when a variety of methods are used, each having different gross chemical environments. Even though a mechanism explaining the nuclear process might be suggested for idealized conditions, unless this is related to the unique chemical-physical environment, the idea is useless in showing how the process can be produced in real material or how the process might be amplified.

Although hot- and cold-fusion produce similar reaction products, they differ in the nature of the NAE in which they can occur and in how the resulting nuclear energy is dissipated. As a result, hot fusion requires a very complex and expensive device in which the energetic reaction is contained and produces significant dangerous radiation. In contrast, cold fusion occurs in a chemical lattice at low energy and produces essentially no radiation. The NAE supporting the hot fusion type of reaction has been studied for over 60 years at great expense while the role of a much different NAE in initiating the cold fusion reaction has been given very little attention. This disparity in support must be corrected before the energy from fusion can be fully developed. The effort to make hot fusion practical has largely failed after spending over 21 billion dollars and growing. It is now time to try a less expensive and perhaps a more practical approach.

Cold fusion has the potential to be so disruptive to society that science is not the only important issue. Policy based on the consequences of its development is also important because widespread commercialization will have enormous consequences, both good and bad. A few of the good consequences are:

1. An unlimited source of energy becomes available.
2. The extraction of deuterium from water and the use of deuterium to generate energy results in no harmful products. It eliminates the production of carbon dioxide and the threat of global warming.
3. The energy source can be small enough to power each building, thereby eliminating cost of energy distribution.
4. The source of energy (deuterium) is available to everyone without restriction.
5. The cold fusion process can be used to eliminate radioactive waste.
6. Desalination of water becomes practical for agricultural use.
7. Understanding will result in new discoveries.

Cold fusion is a major discovery that is ignored at the peril of nations and mankind.

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