A Student's Guide to Cold Fusion

Edmund Storms
KivaLabs, Santa Fe, NM
(updated, April 2012)

Abstract

Evidence supporting cold fusion (LENR) is summarized and requirements an explanation must take into account are justified. A plausible nuclear-active-environment is identified by ruling out various possibilities and by identifying an environment that is common to all methods used to produce LENR. When this environment is combined with a plausible mechanism, many testable predictions result. These insights and proposals are offered to help clarify understanding of LENR and to suggest future studies.

FOREWORD

My interest in cold fusion began shortly after Pons and Fleischmann announced their claims in 1989, while I was a conventional research scientist working at Los Alamos National Laboratory (LANL) on methods to produce nuclear energy for applications in space. A Ph.D. in radiochemistry from Washington University in St. Louis gave me knowledge about both material behavior and nuclear interaction. I mention this only because "believers" in cold fusion are sometimes identified in critical writings as being ignorant and/or gullible. The only difference between my approach and that of skeptics was my willingness to explore the idea. Since retiring from LANL 22 years ago, I have continued to investigate the subject using laboratory research and to write papers including several scientific reviews and a book. The large collection of references, now nearly 4000 acquired in this effort, was used to create the original LIBRARY on www.LENR-CANR.org. Jed Rothwell keeps this collection of literature up to date and the website functional.

Literature on the subject of cold fusion has grown beyond a point where casual reading can lead to useful scientific understanding. My book[1] provides a good primer for the open-minded student, while the fascinating history of the field can be enjoyed in several books[2-8], although a few take a negative and frequently inaccurate approach[9-11]. Personal accounts of several individual experiences[12, 13] are also available. Someone wishing a non-technical understanding should read the interesting book by Rothwell[2], that can be down-loaded in several languages, or "Excess Heat: Why Cold Fusion Research Prevailed" by Charles Beaudette[14][1] The non-technical sections of LENR-CANR.org provide additional information. Information of a non-technical nature can be found at www.coldfusionnow.org.

This Guide is designed to give a technically trained person an overall understanding of the claims and evidence, with an emphasis on brevity. I have chosen only a sample of useful papers, with frequent reference to reviews where more complete information can be found. Much of this information can be obtained in full text from LENR-CANR.org. Once the reality and extent of the phenomenon are established, the next goal is to show

[1] http://www.amazon.com/Excess-Heat-Research-Prevailed-Edition/dp/0967854830/ref=sr_1_3?ie=UTF8&qid=133468).

how this behavior can be explained. Many theories have been suggested but none has given sufficient understanding or has met the requirements I think are necessary. Rather than describe each proposed theory, the general requirements a theory must meet are given. This approach is offered as a guide for future theoreticians.

Many people want to know how to replicate the claims. This Guide does not provide such information because no certain method has been published. Success or failure will largely depend on creating the required conditions, largely by following general guidelines. Nevertheless, the behavior has been replicated hundreds of times in laboratories located in at least 12 countries. When people have achieve success, the methods used are not always revealed in detail for commercial reasons or because the true reasons may not be known. Adding to the difficulty is the need to accurately measure energy and/or the few nuclear products. Such measurements require significant skill and expensive equipment generally not available outside of major laboratories. Tests without such equipment can be fun and educational, but they should not be expected to produce unambiguous effects. Nevertheless, understanding the general conditions and behaviors described in this Guide will improve the likelihood of success for amateurs and professionals alike.

GENERAL INTRODUCTION

Although I offer the LENR process as a real and reproducible effect, albeit with difficulty, not all observed heat energy can be attributed to a nuclear reaction. Unexpected and significant chemical sources do exist and can confuse the conclusions. Energy can only be attributed to LENR if a nuclear product is detected or if the energy greatly exceeds production from any plausible chemical source. These requirements have been met on many occasions but not in every published experiment. Nevertheless, any extra energy made using conditions known from more complete work to cause LENR is attributed to LENR in the following discussion.

To properly understand the nature of cold fusion and the meaning of the term, a little history is required to show how this phenomenon relates to what is conventionally called “hot-fusion”. An unsuccessful effort was made first in 1926[15] to initiate fusion between deuterons. A fusion reaction was produced much later when enough energy was applied to the deuterons in plasma, which eventually resulted in a large research program [16] based on what is called hot fusion. The present organization devoted to making the method practical is called ITER (iter.org). Over 70 years has been devoted to this goal and well over 25 billion dollars (2012 $). Unfortunately, useful energy has not yet been produced and another 5 billion dollars is requested before this goal might, or might not be achieved.[17]

In contrast to this well accepted and understood method, Martin Fleischmann and Stanley Pons[18] in 1989 at the University of Utah succeeded in producing significant energy from what appears to be d+d fusion without application of high energy. Equally impressive, they used only about $100,000 of their own money. This process is unique and important because it can occur at a rate sufficient to make useful energy in a simple device and it involves an entirely different mechanism than the one presently understood

in nuclear physics. A summary of the difference between hot fusion and cold fusion is shown in Table 1. Because the new process has been found to cause many nuclear reactions besides fusion, it has been renamed "low energy nuclear reaction" (LENR) or "condensed matter nuclear science" (CMNS), which are the terms now in general use. When this mechanism is initiated using the electrolytic method, the result is called the Fleischmann-Pons Effect in honor of the initial discovery.

TABLE 1

Cold fusion and hot fusion compared

COLD FUSION	HOT FUSION
Occurs only in special solids.	Occurs in plasma or when enough energy is applied.
Responds to modest energy but not required.	Requires high energy.
Uses protium (H) or deuterium (D).	Uses tritium and deuterium
Makes mostly helium (^{4}He) when D is used.	Makes tritium and neutrons.
Produces insignificant radiation.	Produces significant radiation.
Can be initiated in simple devices at high O/I levels.	Requires a huge machine to produce high O/I levels.
Has been studied for 23 years using about $0.5 B.	Has been studied for over 70 years using well over $25 B.
Energy generators can be located in each home.	The energy generator is huge and must be located well away from populations.

Steven Jones[19] at BYU also claimed to initiate nuclear reactions in an electrolytic cell, but he looked for the radiation expected to result from hot fusion, which he claimed to detect at very low level. He called this process "cold fusion" because he did not apply energy normally required to cause hot fusion. This radiation appears to result from an entirely different process compared to the one Fleischmann and Pons discovered, as is explained below. Consequently, the two observations should not be confused, as occasionally happens in popular articles. Nevertheless, the Jones Effect is important because it can help explain the presence of tritium in the earth's crust,[20] but it is not a source of useful energy because the reaction rate at such low applied energy is trivial.

The LENR process is unique because it appears to operate at high rates in special solid environments present in various metals and compounds. This environment apparently acts as a catalyst to lower the barrier between the hydrogen[2] and other nuclei, for which high energy is normally required, and to carry away the resulting nuclear energy without producing significant energetic radiation. Consequently LENR involves the chemical environment in ways not presently accepted by conventional science, which caused rejection[11] when the claims could not be easily replicated. While I agree that LENR cannot be produced in ordinary materials, only lack of imagination stands in the way of discovering where it can occur – because it clearly does happen. Indeed, if a small fraction of the money spent on the still unsuccessful hot fusion program had been used to understand LENR, acceptance would have been achieved much sooner and a clean, cheap source of commercial energy might be available today.

[2] When the word "hydrogen" is used, it means all isotopes of hydrogen, which are protium (p), deuterium (p+n), and tritium (p+2n). Protium and deuterium are both stable, but tritium decays to ^{3}He + e + neutrino with a half-life of 12.3 years.

Interpretation of LENR is complicated because radiations from what look like hot-fusion-type reactions are occasionally detected at very low levels during conditions typical of LENR. As more attention is applied and sensitive instruments are used, an increasing number of unexpected nuclear reactions are being discovered. As a result, we must consider that not all anomalous nuclear products are related to LENR when the production rate is very small. In contrast, the rates associated with LENR are huge, being near 10^{12} events/sec when 1 watt of power is produced from deuterium. This huge difference in rate differentiates LENR from all other potential sources of unexpected radiation. Many explanations ignore this fact to their disadvantage.

The main nuclear product when deuterium is used is helium (^{4}He)[21], along with detection of occasional tritium and heavy-element transmutation products. Significant energy production, but with different nuclear products, has been observed when ordinary hydrogen is used instead of deuterium, as will be described in more detail later. An important question needs to be answered. Does the energy production from deuterium involve the same mechanism as when ordinary hydrogen is used? I believe Nature has only one basic environment and mechanism to cause such a novel process, regardless of which hydrogen isotope is present in the nuclear reaction. This issue will be addressed as we go along.

Before discussing the mechanism, you need to believe the observations are not the result of error, wishful thinking, or artifacts, as skeptics frequently imply. You can easily verify for yourself which laboratories throughout the world have demonstrated the behavior simply by searching the LIBRARY section of LENR-CANR.org or reading my book[1]. The popular conclusion that the effect has not been replicated is not true and this fact has been ignored since 1991. A more accurate statement is: Replication is possible but difficult and not likely to succeed without considerable effort, knowledge, and luck. Like all poorly understood and difficult studies, failure results because of ignorance, not because the claim is impossible. This simple fact seems difficult for some people to accept. If failure were used to reject new discoveries, we would have no devices based on transistors, no airlines, and most discoveries in medicine would be stopped before they could be perfected. Nevertheless, failed studies are useful because they help refine the boundaries of the parameter space in which the process operates and can be used to test proposed mechanisms.

The challenge now is to explore how an explanation might be constructed. Hundreds of attempts have been made, but without showing how reproducibility or energy production could be improved. The theoretical approaches are so divergent and complex, even a useful summary is impossible. So with apologies to theoreticians, I will describe some requirements I believe all theories should consider, with details provided in Chapters 5 and 6.

Understanding must start by making assumptions, as is required when attempts are made to explain any new phenomenon. Success of the explanation is determined by how correct these assumptions turn out be. As a start, I will assume hot fusion and LENR to

be entirely different and unrelated processes. Consider the obvious facts - hot fusion uses brute force to bring nuclei close enough to fuse, generally in very hot plasma[3]. In contrast, LENR occurs in a solid structure where high energy is not present and cannot accumulate without altering the structure. In fact, LENR-type reactions cannot be initiated in "normal" structures even when very high energy is applied in the form of increased temperature, as years of experience in the chemical industry have demonstrated. When a fusion reaction is occasionally caused by ion bombardment or intense laser light, the hot fusion-type reaction is always observed. In summary, hot fusion requires extra energy to produce the conventional reaction paths ($n+^3He$, ^3H+p) and LENR requires a special environment to produce only helium without significant detectable energetic products. To make the difference clearer, the former requires high energy and is slightly sensitive to the environment while the latter is very sensitive to the environment and does not need extra energy. This distinction is very important to keep in mind because both processes can occur in solid materials at the same time and each is influenced by the chemical environment.

A second assumption can be suggested: — something must change in normal materials before the LENR-type reaction can occur. The rarity and the difficulty with which these reactions are produced can only be understood if these required changes are difficult and rare. The challenge is to correctly identify this unique environment and only then propose a mechanism. I call this special condition the nuclear-active-environment (NAE) to distinguish it from the condition that exists in the normal chemical structure. In short, normal chemical environments do not influence nuclear reactions, as is correctly believed by conventional science, but unusual structures may. Formation of such structures would be expected to follow all the rules known to apply to chemical reactions, while the rules used in nuclear physics would apply to the subsequent mechanism causing the nuclear process. Here is where a marriage between chemistry and physics is required, but the courtship has been long and rocky. Some relationship counseling will be provided in Chapter 4.

Unfortunately, the nature of the NAE has been difficult to discover because the reactions only appear in very small regions having properties much different from the surrounding material. The problem is to identify this unique structure; not reject the entire idea just because a normal material cannot be involved. Once this unique structure or condition is identified and can be created on demand, difficult replication will be a frustration of the past and a source of clean energy will be available for the future. In addition, only then can a proposed mechanism be tested and verified.

[3] Plasma is ionized gas generally at low pressure. The energy of the ions (temperature) can be very high and limited only by how fast energy can be added to compensate for energy loss. The ions can be caused to bombard a solid surface or they can interact with each other. Both methods can be used to initiate hot fusion when the ions are D^+ and/or T^+.

CHAPTER 1
Quick Overview

This quick overview provides basic information about LENR for a casual student. More details will be added in later chapters. The goal is to demonstrate the existence of a real phenomenon having many similar behaviors. Making sense of these behaviors has not been easy because this has required a basic change in how nature is viewed, especially by people trained in physics. Part of my goal is to paint a simplified picture into which plausible mechanisms might fit, to show why many mechanisms do not fit this picture, and to suggest a mechanism that might actually explain the behavior. This is done in later chapters. Hopefully, these ideas will stimulate discussion and help clear away some confusion even if they are not accepted or may even be wrong. So, please accept the Guide as an educational tool.

Palladium deuteride was once thought to be unique in its ability to host LENR reactions. Now many other metals and metal alloys have been found to produce the same novel effects. Nevertheless, in each case, success depends on how the material is treated beforehand; to the chemical environment the material is exposed during the process; and to the method used to apply energy. Apparently, the chemical environment is as important as the mechanism, a fact that is frequently ignored. These chemical effects add additional complexity, which partly explain why the effect has been so difficult to replicate. In the absence of knowing how to create the required condition or even what important conditions are present in a material, LENR occurs essentially by chance. Only now, after 23 years are some of the required conditions for success being understood.

What methods can cause LENR? The first reported method[18] used electrolysis to react palladium with deuterium to make beta-PdD_x.[4] Platinum has also been electrolyzed with D_2O[23] to make energy even though platinum does not react with deuterium. Titanium has been electrolyzed with D_2O[24] to produce extra energy and some nuclear products. Electrolysis has also produced extra energy when nickel cathodes are used with an electrolyte based on H_2O[25, 26]. Increased temperature[27-29], applied RF energy[30], and laser light[31-34] appear to increase energy production. Use of voltage sufficient to create plasma[35-37] in the electrolyte has been found to generate a variety of anomalous nuclear reactions when the cathode is palladium, tungsten or carbon[38]. The kind of atom dissolved in the electrolyte and subsequently plated on the cathode plays a dominant role in determining which nuclear reaction occurs on the cathode. Thin layers of material plated on glass[39, 40], plastic, or platinum[41] have also become nuclear active when electrolyzed. As this brief summary shows, many nuclear effects can be generated using variations on the electrolytic method when applied to several kinds of materials, not just palladium – but the rest of the story gets even more interesting.

[4] Beta-PdD_{1-x} is a face-centered-cubic structure (fcc) with x having a variable value from about 0.32 to 0.01. The value of x is determined by temperature and applied D_2 pressure and the resulting defect structure has metallic properties. The Pd-H (D) system has been studied for over 60 years and the properties are well understood[22].

Simply exposing finely divided metal of various kinds to hydrogen isotopes can cause LENR. For example, some nanometer-size palladium particles become nuclear active when exposed to deuterium gas. This palladium powder can be freestanding as "palladium-black"[42] or attached to a carbon surface[43, 44], as in a conventional chemical catalyst. Even a flux of deuterium passing through palladium metal is found to generate a variety of nuclear reactions[45] and energy[46, 47]. Typical of the LENR process, none of these results are produced every time or when similar kinds of material are used. Something very unique and rare must be present.

Energetic ions, obtained by discharge in gas containing hydrogen isotopes[48, 49] have been used to initiate LENR. In all cases, ion energy is far below that thought necessary to cause hot fusion. The resulting nuclear reactions are very sensitive to the material used as the cathode.

Certain complex metal oxides[50-52], capable of dissolving some deuterium, are found to produce extra energy as the deuterium is caused to move through the structure by applied voltage. Similar electrodiffusion of D^+ in beta-PdD may also produce anomalous energy [53-55]. The extra energy is assumed to result from LENR.

Bubbles, generated by sonic energy passing through a liquid, can collapse on a metal surface, a process called sonofusion. When this happens, the bubble content is injected into the metal as plasma. Use of heavy water injects a mixture of D^+ and $O^=$, which produces LENR in a variety of metals used as the target[56-59]. Normal water may produce similar novel effects, although duplication has been spotty[60]. This effect is not the same as acoustic cavitation, as happens when hot fusion is caused to occur in a collapsing bubble.[61, 62] Once again, likely hot fusion-type reactions must be separated from LENR.

Anomalous effects have been seen during a variety of chemical reactions when deuterium is present[63] or when material is subjected to mechanical shock. Sudden heating of titanium charged with D_2 [64] or cooling of titanium in D_2 gas[65, 66] results in a few neutron emissions. Many chemical reactions involving deuterium are reported to generate neutrons, including the setting of Portland cement.[67] These few detected neutrons may be produced by a hot fusion-type reaction where high voltages are concentrated during crack formation rather than by LENR.

Nuclear effects have also been reported to involve biological systems in the presence of both D_2O[68] and H_2O[69, 70]. Even radioactive cesium (^{137}Cs) apparently decays much faster when certain bacteria are present in the solution with the isotope.[68, 71] Tritium (^3H), when reacted with finely divided titanium[72], also apparently experiences a change in its decay rate, as demonstrated by Reifenschweiler. This aspect of LENR has the potential to reduce the amount of radioactive waste generated by the fission process.

The chemical environment can even influence the hot fusion reaction. When D+ ions are given a few kilovolts of energy and used to bombard various materials, the resulting normal hot fusion reaction is found to be sensitive to the concentration of electrons in the

material.[73-75] This is not the case when very high energy is used because the weak chemical environment can then be overwhelmed.

Only a few studies have measured nuclear products at the same time as anomalous energy. These measurements show a direct relationship between energy and ^{4}He production[21] when deuterium is present, as first demonstrated by Miles and Bush. On the other hand, tritium and neutron emissions, typical of hot fusion, are seldom associated with detected heat, although occasionally X-ray emissions are observed. None of the products have the high energy typical of hot fusion. This difference in type and energy of the nuclear products is important because it provided the reason for past rejection of LENR and still causes confusion when observations are interpreted. Nevertheless, absence of dangerous radiation is a gift to researchers and to potential home use.

Ordinary hydrogen is also found to be nuclear active in some environments, but what could possibly be the nuclear products? Conversion of Ni to Cu by reaction with a proton is proposed to produce significant energy when a specially treated nickel surface is exposed to hydrogen gas[76-79] at high temperatures. Similar transmutation-type reactions have been observed in other studies. For example, when electrolysis is used, potassium deposited from the electrolyte on the cathode is claimed to convert to calcium by reaction with a proton[80, 81]. Many other transmutation reactions have been reported, but too numerous to mention here. Some of these have produced radioactive[82-84] isotopes, which is a rare result. Nickel even appears to produce radioactive tritium[85] when it is repeatedly loaded and deloaded with ordinary hydrogen gas.

An important conclusion is revealed. If the detectors are sufficiently sensitive and if enough care is taken to look, the chemical environment can be shown to influence several nuclear reactions under very unexpected conditions. Because rejection of these claims is so strong, only a few effects have been replicated often enough to justify full acceptance. As a result, a powerful tool, perhaps able to solve many problems, is being ignored.

A proposed explanation must take into account the arrangement of atoms and electrons present in the proposed region where LENR occurs. All too often, the actual chemical condition is ignored. For example, the cathodes used by Fleischmann and Pons were not pure PdD in the active surface region, as they and many people assumed. Instead, a complex alloy containing D, Li, O, C, Pt, Pd, and frequently other impurities leached from the Pyrex container or wires[86-89] are present. Detailed examination under high magnification shows non-uniform distribution of these impurities and a very complex physical structure, not typical of ideal PdD. Occasional transmutation products are also found. Consequently, explanations based on the properties of pure PdD would not apply, yet this assumption is frequently made and used as the basis for a mechanism. Consequently, if the phenomenon is to be explained, the mechanisms must be based on material know to be present, not some ideal structure. This requirement has frequently not been met.

New methods are being explored and old ones are being replicated. Skeptics predicted that cold fusion was an artifact and would disappear when better instruments and

techniques were used, but this has not happened.[90] On the contrary, the effects have been more widely reported at increasing intensity. Clearly, the unique mechanism can be initiated many different ways, in many chemical structures, and involve all isotopes of hydrogen. The challenge is to deduce what these chemical structures and methods have in common.

CHAPTER 2
Energy Production

2.I. Introduction

Now for the details, which will require some repetition of what you have already learned. All the various methods have one thing in common – energy production. Sometimes the amount of energy is too large to result from conventional reactions and sometimes no energy at all would be expected from the conditions being used. In either case, the energy is attributed to LENR. While this might not be the correct explanation in all cases, the patterns of observed behavior are worth exploring in the context of LENR. First, the tools used to measure energy need to be understood

2.II. Explanation of the Calorimetric Method

Measurement of energy production requires a calorimeter, which is simple in concept but complex in application. I can assure the reader that many years of experience using every type of calorimeter have taught me all the difficulties of making accurate measurements and the many errors skeptics are quick to point out. Nevertheless, the method can be mastered and used to obtain accurate values, but only when care is taken to understand the limitations.

Several kinds of calorimeters are commonly used, which include isoperibolic, flow-type, and Seebeck. Each of these is called isothermal in contrast to the adiabatic type that uses the rate of temperature change where energy (Joule) is being accumulated. The adiabatic method is seldom used, although Fleischmann and Pons were an exception.

Isoperibolic calorimetry uses the temperature difference (ΔT) across a thermal barrier to determine the amount of thermal power passing through the barrier. Accuracy depends on ΔT being known over the whole barrier area and being stable. Common use of the cell[5] wall as the thermal barrier and measuring temperature within the electrolyte can result in significant error because unexpected temperature gradients are usually present. These gradients are caused by random convection currents in the liquid. In this case, accuracy depends on proper design of the cell, location of the temperature sensors, and the stirring rate of an internal stirrer.[91] This method requires suitable calibration, usually by electrolyzing an inert electrode. Use of an internal heating element for calibration is not recommended unless the convention gradients are reduced by stirring or by simultaneous application of electrolytic current. Changes in external conditions, such as caused by applying a magnetic field or changes in room temperature, can produce unexpected error. For the latter reason, such cells are frequently placed in water held at constant

[5] The cell, generally glass, is used to hold the electrolyte through which current is passed to cause LENR at the cathode.

temperature. A refinement of this method uses a thermal barrier external to the cell[92-94], a so-called double-wall calorimeter. Such a design is much less affected by gradients within the cell and can be made very sensitive to generated thermal power.

A flow-type calorimeter captures released thermal power in a flowing fluid and the resulting temperature change of this fluid is measured. If no energy is lost from the calorimeter, the amount of thermal power can be obtained using flow rate, temperature change of the fluid, and its heat capacity, the so-called absolute method. However, complete capture of all energy is very difficult. Consequently, the calorimeter must be calibrated by using an internal heating element or by electrolyzing an inert electrode. Isolating the calorimeter from the environment and achieving a constant, known flow rate can be a challenge. Nevertheless, an uncertainty of better than ±0.05 watts can be achieved. The design used by McKubre *et al.* is especially good and well documented.[95, 96]

The Seebeck calorimeter generates a voltage produced by the temperature difference across a thermal barrier containing thermocouples or commercial thermoelectric converters.[97-99] This barrier completely surrounds the heat source, with the outside kept at constant temperature. Because all parts of the surrounding wall are sensitive to heat flow, loss of energy through each part of the thermal barrier is summed, regardless of where heat energy leaves. Unfortunately, not all locations are completely equivalent. As a result, the calibration constant is sensitive to where the heat source is located within the thermal envelope. Installing a fan can reduce this problem. On the other hand, this method is not sensitive to where heat is generated within the electrolytic cell containing the heat source. Only the position of the cell must be kept constant within the thermal envelope. This method must be calibrated using either a resistor within the electrolyte cell or a dead cathode.

Many variations of these calorimeter designs have been used. Reliable measurement of anomalous power of ±50 mW, superimposed on 15 watts of applied electrolytic power, can be routinely achieved. Some designs can measure excess power as small as 1 mW, as was claimed by Fleischmann and Pons.

2.III. Sources of Anomalous Energy

2.III.1 Description of Electrolytic Method

An electrolytic cell consists of a liquid made conductive by addition of various soluble salts. For cold fusion, the added material has been LiOD, Li_2SO_4, K_2CO_3, or H_2SO_4. Two metal electrodes are placed in the liquid, with one made positive (anode) by an external power supply and the other made negative (cathode). The cathode is typically palladium and the anode is platinum, although other metals have been used. When current is passed from one electrode to the other through the liquid, chemical reactions occur on the electrode surfaces, with D_2 formed as bubbles at the cathode and O_2 gas at the anode when the electrolyte is D_2O. Some of the deuterium reacts with a palladium cathode to form beta-PdD. The gases escape from the cell into the surrounding atmosphere through a small opening if this is an “open-cell”. This escaping gas carries chemical energy that must be added to any energy being made in the cell to properly determine the energy

resulting from LENR. If a catalyst is placed in the cell to recombine the D_2 and O_2 back to D_2O, the cell can be sealed and is called a "closed-cell". This design avoids the errors related to loss of gases from the open cell. The cell frequently contains a resistor for calibration, a thermistor to measure the temperature, and an additional platinum electrode for measuring the open-circuit-voltage (OCV)[6]. Various methods are also used to measure the D/Pd ratio of the cathode, including measuring its resistance, weight gain, and production of orphaned oxygen.[7]

2.III.2. Results from Electrolytic Method

Pons and Fleischmann were the first to claim anomalous heat generation using electrolysis, during which they used an isoperibolic calorimeter. This work was subjected to considerable analysis and debate, but was eventually found to be sufficiently accurate to support their claim[100, 101]. Since this work was published, well over 200 claims for anomalous energy using electrolysis have been published. Most of these studies measured several samples of palladium, with some being active and some inactive. In a few cases, the same batch of active palladium was studied in different laboratories [102, 103] with similar success. Once an active cathode is discovered, it can be used to produce LENR at will, with total reproducibility until it eventually dies as additional material is electrodeposited on the surface. This behavior prevents commercial application of this method for energy production. Fortunately, several other methods now produce a growing number of positive results without this limitation.

Until recently, anomalous energy was assumed generated within the β-PdD structure. Many recent observations indicate that only small regions in the surface are active and these rapidly turn off and on[104]. Presumably, a region starts to generate energy, heats up, expels deuterium, and then turns off. Rapid repetition of the process at many locations produces apparent steady energy. Occasionally, energy density is sufficient to cause local melting.[87] Melting is possible because many impurities lower the melting point well below that of pure palladium (1554.9°C).[105, 106] Care must be taken because what may appear to be melting might actually be preferential deposit of impurities around vents releasing D_2.

When the electrolytic method is used with a palladium cathode, everyone who makes suitable measurements always sees six characteristic behaviors. These are:

1. The ability to make extra energy is influenced by the average D/Pd ratio of the cathode, with a critical value being required before any extra heat can be expected, as first demonstrated by McKubre *et al.*[107]. This critical value differs between studies because only the average composition can be determined, which depends on the method used, the shape of the cathode, and

[6] The OCV is determined by measuring the voltage generated between the cathode and an extra electrode while current is not flowing between the cathode and anode. This voltage is produced by chemical effects on the cathode surface and can be used to estimate the D/Pd ratio at the surface.

[7] Orphaned oxygen is excess oxygen resulting because some deuterium has reacted with palladium and is no longer present in the gas to convert O_2 to D_2O at the internal catalyst. This results in a pressure change or extra gas in a closed cell that can be measured to determine how much deuterium has reacted.

the density of cracks at the surface. Typically, the average critical value lies between D/Pd=0.80 and 0.90. The important surface composition is not normally measured, but appears to be above D/Pd=1.5 and perhaps as high as D/Pd=2.0[108, 109], as shown in Fig 1. Failure to reach a sufficiently high composition on the surface, regardless of the average composition, can explain occasional failure of highly loaded samples and unexpectedly high surface compositions can explain why some samples having a low average D/Pd ratio will, nevertheless, produce extra energy. Failure to achieve the required surface composition is a major reason for many past failures at replication.

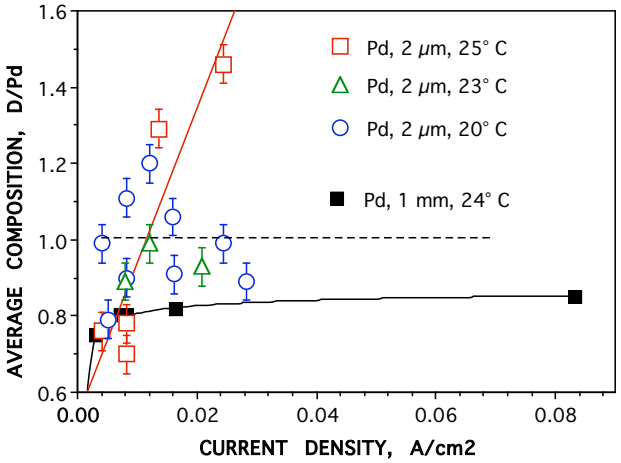

FIGURE 1. Average compositon of Pd as a function of applied current density. The values for the thin films are assumed to be close to the true surface composition.

2. Current must be maintained for a critical time. This time is variable and presumably depends on how rapidly the surface can acquire the active structure and/or composition. This time is short for very thin layers of Pd, while it can be as long as months for bulk palladium. Failure to wait long enough is among the reasons people failed to replicate. The other methods used to cause LENR do not exhibit as much delay. Presumably, if the NAE could be created beforehand, this delay would vanish.

3. Current density must be above a critical value, as shown by a few examples in Figure 2. Applied current determines the surface composition, with a value between 100 mA/cm^2 about 200 mA/cm^2 being required to produce a surface composition able to initiate detectable energy production when bulk palladium is used. Presumably, this amount of current is required to produce enough D+ ions to compensate for the loss of deuterium from the backside of the active surface or from surface-penetrating cracks. Thin layers of palladium deposited on platinum do not require such a high critical current because backside loss is trivial, provided the layer is well bonded[41]. Such samples can show anomalous energy at currents near zero.

4. Inert palladium can sometimes be activated by adding certain impurities to the electrolyte[110]. These impurities are proposed to help the surface achieve a higher deuterium content and/or suitable structure. Use of what is called a super-wave[111] can also increase the D/Pd ratio and heat production

5. LENR occurs in only a small fraction of samples, but more often in certain batches than in others[110, 112]. In fact, all physical properties of palladium are found to be batch specific, making this metal highly variable in its general behavior, even in conventional applications. Electroplated palladium using the so-called co-deposition method[113, 114] has a higher success rate, although it also can produce highly variable results depending on conditions used during plating.

6. Presence of too much light water in the D_2O electrolyte will stop the reaction [102]. Even a brief exposure to laboratory air can render D_2O useless. Such carelessness explains many early failures. In addition, not all sources of D_2O are pure enough to insure success even when they are free of H_2O.

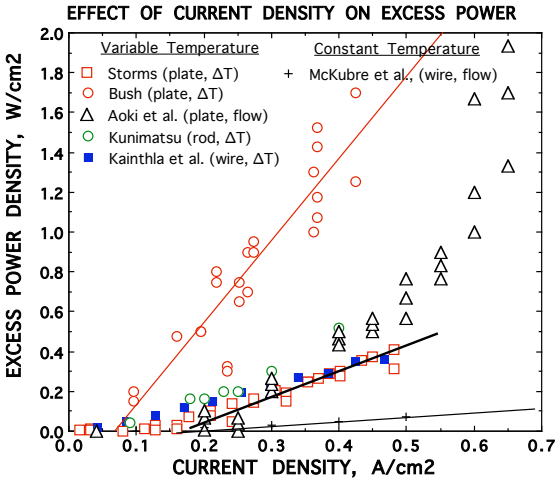

FIGURE 2. Effect of current density on excess power production.

The electrolytic method has met all of the criteria science requires to accept anomalous claims. Anomalous heat production has been independently duplicated many times with values frequently far in excess of expected error, the results show the same patterns of behavior regardless of the apparatus used or where the work is done, and many reasons why replication is difficult have been identified. Knowing the source of energy should not be required to accept the observations. Fleischmann and Pons have been proven correct and the skeptics have been shown to be wrong. Only missing is general recognition of this fact and suitable apologies.

2.III.3. Effect of Temperature on Heat Production

Most measurements of heat production using electrolysis are done near room temperature. On a few occasions, the temperature was changed to determine its effect or

the process was designed to operate near the boiling point.[27, 29, 106, 115, 116] As expected, such temperatures result in faster chemical attack of materials exposed to the electrolyte and cause increased buildup of impurity on the cathode surface. In fact, Zhang[117] found that pre-electrolysis at the boiling point improves success of subsequent heat production at lower temperatures. Storms[118] explored the role of surface condition in 1993 and McKubre *et al.*[119] emphasized the importance of this impurity layer based on their extensive studies. This variable surface layer makes a decision about the effect of temperature alone difficult, but increased temperature does seem to increase the rate of heat production.

A liquid containing an eutectic alloy based on KCl-LiCl-LiD was used to cause LENR at the palladium anode[8] above 350°C[120]. Significantly more power was produced from the same amount of palladium compared to when electrolysis of water has been used. Attempts to replicate the method were undertaken by Okmoto and Nezu.[121] Yuan *et al.*[122] using palladium and by Tsvetkov *et al.*[123] using titanium as the active electrode (anode). This method is difficult because of the high temperature and corrosive properties of the electrolyte.

2.IV.1. Description of the Gas Loading Method

A suitable material is placed in H_2 or D_2 gas, generally at pressures well above one atmosphere. The material is heated and LENR energy is found to increase as the temperature increases. As usual, proper treatment of the material is critical. Because of its simplicity and modest energy requirement, the method has great promise as a commercial source of power.

Because the reaction rate is increased by temperature, a material in which significant power is being generated will self-heat to potentially destructive temperatures unless active intervention is used. Fortunately, the concentration of hydrogen in the NAE will decrease with increased temperature. Interaction between these two effects would tend to produce a stable temperature at some high value. Application of this energy source will depend on how well this instability can be controlled and the temperature at which stability can be achieved.

2.IV.2. Results from Gas Loading

Arata and Zhang[124, 125] at Osaka University in Japan were the first to generate anomalous energy using finely divided palladium. This powder was contained in a palladium capsule, which was pressurized with very pure deuterium generated by electrolysis. The claim was duplicated by McKubre *et al.* at SRI [44, 126] with Prof. Arata's help. After this work was published, Case[127] heated a carefully selected commercial palladium catalyst in deuterium gas and reported anomalous energy and helium. This claim was also duplicated at SRI[44] with Case's help. Such help by people who have made the effect work is critical because the critical treatment is never fully described in publications.

[8] Deuterium has a negative charge in this electrolyte, which causes it to react with the anode without producing D_2 gas.

Iwamura *et al*. [45, 128, 129] at Mitsubishi Heavy Industry in Japan deposited a thin layer of palladium (40 nm) on layers of CaO that had been deposited on palladium. When deuterium was caused to diffuse through this sandwich, several nuclear reactions involving nuclei deposited on the surface were detected. The work is important because its shows very clear transmutation reactions involving up to 6 nuclei of deuterium. Attempts at replication are underway.[130-133] This work will be more fully described in later chapters.

Clarke *et al.*[126] detected ^{3}He in an Arata-type cell provided by McKubre after a delay following energy production. The helium could be explained by decay of tritium produced during the study.

Itoh *et al.*[134] reacted palladium with deuterium, then coated the material with copper, after which the deuterium was removed by heating in vacuum. The amount of tritium increased substantially when the initial average composition was over D/Pd=0.85.

Tritium was found in nickel wires after being electrically heated and cooled many times in ordinary hydrogen[85]. The resulting hydride layer, in which tritium was found, was only 20-30 nm thick.

Nickel rods were specially treated, after which they produced extra energy when exposed to H_2 at temperatures above 250° C.[76, 77, 135, 136] Even more extra energy is produced by nickel powder.[79, 137]

2.V.1 Description of Gas Discharge Method

A few thousand volts are applied between two electrodes in low pressure D_2, usually as a short pulse of current to avoid over heating. Plasma is created from which D+ ions rain down on the cathode. Because these ions seldom experience the full amount of applied voltage, they do not have enough energy to cause hot fusion, yet LENR has been demonstrated many times by various laboratories. Important understanding results from this method because the nuclear products have been discovered to be sensitive to the material from which the cathode is made. Nevertheless, the transmuted products actually form in a complex structure [138] on the cathode surface. Once again, the nature of the material is important because the active surface is not ordinary material.

2.V.2 Results using Gas Discharge

Claytor et al.[48], during a well-documented and through study at LANL and later in a private laboratory over many years, generated tritium by subjecting certain alloys to pulsed discharge in D_2 gas at modest voltages (<7000 V). The amount of tritium generated depends on the material used as the cathode, with certain complex alloys being more productive than pure palladium. Steady research over the years, has enabled this method to become reproducible and a potential source of useful tritium without detected neutron production.

Studies of gas discharge have been ongoing since 1990 at the Scientific Industrial Association “Luch” in Russia. Various laboratories in Russia have continued these

studies and have supported growing evidence for extra energy, transmutation, and radiation having unusual behavior.[139-144]

Dufour *et al.* have used a variation of the gas discharge method since 1993 to show production of transmutation and energy when the method is applied to uranium[145] and palladium cathodes[49, 146].

2.VI.1 Description of the Electrodiffusion Method

Electrodiffusion is a process whereby ions dissolved in a material are caused to move under the influence of applied voltage. The enhanced diffusion rate is proportional to the resulting current density and to the amount of charge on the ion, thereby allowing the effective charge of a dissolved ion to be determined[147]. For example, the effective charge on hydrogen in $PdH_{0.67}$ is +0.30±0.05[148], with an apparent increase in positive charge at higher H/Pd ratios[149, 150]. In other words, the proton acts like it is not fully neutralized by the surrounding electrons, presumably because the required electrons are located elsewhere. Conventional thinking places them in the conduction band where they cause a change in resistance as the hydrogen content is changed.[151, 152]

2.VI.2. Results using Electrodiffusion

Coehn[153] was the first to concentrate dissolved hydrogen at one end of a palladium wire through which current was passed. Later, various people including Fleischmann [55, 154-156] used this behavior to increase the local concentration of deuterium in palladium wires and cause LENR.

This method was first applied to aluminum oxide by Granite and Jorne[157] without success. Mizuno[158] later obtained excess energy using $SrCeO_3$, which was duplicated with Mizuno's help by Oriani[51] using $SrCeO_3$ containing a little Y and Nb. Mizuno detected gamma radiation he attributed to the radioactive decay of ^{197}Pt.[159] Biberian *et al.* produced energy using $LaAlO_3$[52, 160]. While the amount of extra energy is small, so is the amount of applied energy required to heat the material above about 500° and to generate the voltage required to push D+ through the lattice. As a result, efficiency of energy production is impressive.

Diffusion driven by applied voltage and normal diffusion driven by a concentration gradient may have identical effects as far as the nuclear mechanism is concerned. Consequently, a flux of deuterium ions during electrolysis, as is almost always present, may aid in energy production, as suggested by McKubre[161]. Why diffusion affects LANR is unknown, but might result simply because hydrogen is made more available to the NAE.

2.VII.1. Description of the Sonic Method

A sonic wave is created by a transducer vibrating at the required frequency (20 kHz-1MHz), which creates a standing wave within the liquid between the transducer and a target metal. This wave results in bubbles that collapse on the target. If the liquid is D_2O, the resulting deuterium ions are injected into the surface to cause LENR and the $O^{=}$ reacts with the metal to form a colored oxide on the surface.

This is not the same method used by Taleyarkhan *et al.*[162] to generate neutrons within the collapsing bubbles. In this case, temperatures of thousands of degrees, reached just before the bubble vanishes, may produce a brief hot-fusion reaction, but not LENR.

Intense agitation of a liquid using mechanical stirring or rapid changes in flow rate can generate bubbles by a non-coherent process called cavitation. This process can cause damage to surfaces exposed to the local energy, changes in chemical structure, biological sterilization[163], and perhaps LENR.

2.VII.2. Results from the Sonic Method

Stringham[56, 164] pioneered use of the sonic method to react solid metals with deuterium. Recent change from using 20 kHz to >1 MHz has improved results. Energy and helium production have been demonstrated. Other workers have tried reacting materials suspended within D_2O[165, 166] using this method. Evidence for nuclear products[167] and extra energy is reported.

A number of efforts to generate energy using mechanically created cavitation have been reported using light water[60, 168-171]. A video of the process can be seen at (http://www.youtube.com/watch?v=478A91FoBW4).

CHAPTER 3
Nuclear Products

3.I. Introduction

Once claims for anomalous energy are accepted, identification of its source is the next step. Because of its large magnitude and absence of an obvious chemical source, Pons and Fleischmann suggested the energy came from fusion of two deuterons. This suggestion immediately got them into trouble with the physics community because the expected radiation was missing. Ignored was the importance of ANY energy source having such a large magnitude. Nevertheless, an observed nuclear product is required to support a claim for a nuclear source, which was later found.

The conventional fusion reaction has three potential paths shown in Table 2. Each path contributes the indicated fraction when fusion is caused to occur at high energy, as in plasma. The branching ratio between the neutron and tritium paths is energy independent above about 20 keV, but may be sensitive to applied energy at lower energies[172]. When hot fusion is produced in solid materials, it is slightly affected by the chemical environment [74, 173].

TABLE 2

Nuclear reactions resulting from hot fusion of deuterium

REACTION	ENERGY, MeV	FRACTION
$D+D = He^4 + gamma$	23.9	<0.01
D+D =tritium +proton	4.03	0.5
$D+D = He^3 + neutron$	3.27	0.5

These branches were initially thought to occur with the same fraction when anomalous energy was made in a Fleischmann-Pons cell. Consequently, early rejection of the claims was based on failure to detect significant neutron emission or tritium production. This was the first major error made by skeptics.

3.II. Helium Production

Search for a nuclear product was rewarded by early success in finding ^{4}He.[174] This work was rejected because the required gamma emission is absent and the helium could be assumed to result from contamination by helium from the air.[175, 176] Later studies clearly support the original work of Miles *et al.* The critique by Jones *et al.*[21] is not supported. Clearly, helium is the major nuclear product when LENR occurs in the presence of deuterium. The measured relationship between the amount of energy and the amount of helium (23.8 MeV/atom He) points to the d+d=He reaction because no other nuclear reaction involving deuterium results in ^{4}He with as much energy. Regardless of the mechanism, this reaction is called fusion.

3.II.1. Errors Associated with Helium Production

Helium is measured using a high-resolution mass spectrometer. A major error involves the possibility of air, which contains 5.6 ppm ^{4}He, being mixed with the analyzed gas. Such contamination would be revealed by the presence of argon in the gas, which is present in air at 0.94%. Deuterium gas (D_2), which has a mass very close to helium, can interfere but is usually removed chemically before the remaining gas is submitted to the mass spectrometer. Some mass spectrometers have such high resolution this purification step is not required.

Helium is expected to be located in either the surrounding gas or in the solid structure. When helium is generated within a metal structure, it can only be removed by heating the metal near its melting point[177] unless the helium resides very near the surface. Because the detected helium is found in the gas surrounding the LENR source, it must be produced mostly very near the surface rather than in the bulk. This observation helps locate the NAE.

3.III.1. Tritium production

Tritium was looked for by several laboratories and first found by the group at Texas A&M.[178] Even though numerous replications followed [179, 180], this evidence was summarily rejected because the expected neutrons were missing, with a n/t ratio less than 10^{-6}. Tritium is seldom detected when anomalous heat is produced. When it is detected, the amount is never enough to account for observed energy. Even though tritium is not correlated with energy production, it is clearly a nuclear product that is occasionally detected when several methods for producing LENR are used and when either D or H, or sometimes both, is known to be present.

Will *et al.*[181] used sealed glass electrolytic cells containing a catalyst into which nothing could enter or leave as current passed through the D_2O. An identical cell containing H_2O was run at the same time using material from the same batch of

palladium. These control cells never showed any increase in tritium content. Tritium analysis showed more tritium in the electrode than in the electrolyte. Any tritium present in the palladium electrode before the study could not remain there for long because deuterium quickly displaces tritium from palladium during electrolysis[182]. Similar pieces of palladium from the same batch were analyzed and shown not to contain tritium[183]. Clearly, tritium did not result from contaminated palladium, as some skeptics assumed. In fact, no plausible source of tritium has been suggested to explain these observations. In addition, the amount of anomalous tritium was far in excess of the sensitivity and error of the detector.

Other careful studies have reported too much tritium to be rejected as error or contamination. Bockris and his students[184] found tritium using a palladium cathode and D_2O in an open cell. Shaking the cell could stop tritium formation and increasing cell current (voltage) could increase the production rate. Such behavior could not result from tritium being in the palladium previous to the study or from tritium in the atmosphere. Copper, from an exposed wire, was found on the cathode after the study. This was thought to be present as dendrites, which could be removed by shaking, thereby interrupting the reaction. Because tritium could not be dismissed based on error, attempts were made to discredit the work by suggesting fraud,[185] an accusation later shown to be false.[186, 187] Hundreds of replications have been made at major laboratories including Texas A&M[181], LANL[179, 189], BARC in India [190], universities in Japan[191, 192], and at a major laboratory in Italy[193], to name only a few examples. Tritium can only result from a truly unique nuclear reaction; a fact demonstrated as early as 1990.

3.III.2 Errors Associated with Tritium Production

Tritium is radioactive, decaying by beta emission to ^3He with a half-life of 12.346 years[194]. Tritium is normally detected by converting the gas to water, which is dissolved in an organic fluid that gives off light upon passage of the beta particle. This light is detected by a photomultiplier tube and presented as an energy spectrum and the total number of events. Chemiluminescence, i.e. light produced by a chemical reaction, is a potential source of error. This error is eliminated by waiting for a suitable time after the triturated water is added to the radiation-sensitive fluid or by vacuum distilling the sample to obtain pure water, after which extra light is not produced. Or the beta radiation can be measured directly using an ionization cell and a sensitive electrometer. The amount of accumulated ^3He can also be measured as a function of time with a mass spectrometer and used to determine the amount of initial tritium. Because the emitted beta particle is barely able to pass through a piece of paper, special detector design is required. Although detectable tritium is present in the normal environment, a residue from atom bomb tests and natural sources, the amount is far less than found in LENR cells.

Tritium has been produced using several different techniques, including electrolysis, gas loading, and ion bombardment. In each case, success is very dependent on the material being subjected to the treatment. Of these, the electrolytic method has been given the greatest attention. Unfortunately, electrolysis concentrates tritium that is always present

in commercial D_2O. Therefore, either a sealed cell containing a recombining catalyst must be used or the evolving gas must be collected and analyzed separately for tritium, as has been frequently done. Some studies have attempted to calculate the increased amount of tritium expected from the known separation factor[195, 196], a correction discussed in detail in my book.[1] When the correct methods are used, this correction becomes small or irrelevant.

3.IV.1. Neutron Production

The rate of neutron production is so small and infrequent; the neutrons might not result from LENR at all. A process called fractofusion[197, 198] has been suggested whereby cracks produced within a material can generate sufficient voltage gradient and/or temperature within a crack to initiate a local hot fusion reaction. Even normal rocks have been found to emit neutrons when they are fractured.[199] Suitable cracks are known to occur when various metals form hydrides, including palladium and titanium. Consequently, energetic neutrons must not be assumed to always result from LENR because conventional sources are possible.

Hundreds of attempts have been made to detect neutron emission during LENR, with most reporting no detectable emission. The studies by Takahashi *et al.*[200, 201] are especially important because excess energy production was demonstrated while neutrons were measured and their energy was determined. Electrolytic cells containing a palladium cathode were subjected to alternate high and low applied current, which produced neutrons with 2.54 MeV and between 3-7 MeV, suggesting to the researchers a multi-body process. This idea was further explored using ion bombardment.[202] These energies are close to those expected from the hot fusion mechanism, which suggests they might not come from LENR. After all, applying alternating high- and low-current can also produce cracks with possible fractofusion.

Mosier-Boss *et al.*[203] used CR-39 plastic to detect a few neutrons being emitted from a cell in which Pd was being deposited on a cathode in D_2O. They concluded the neutrons might result from a D-T hot fusion reaction. Presumably, the D-D hot fusion reaction produced tritium (T), followed immediately by the less-likely D-T reaction. The cited paper provides descriptions of other successful efforts to find neutrons using electrolysis by these researchers.

De Ninno and co-workers[204, 205] were the first to find some neutrons that might have resulted from LENR by temperature cycling of titanium in D_2 gas. This observation prompted many attempts[206, 207] to replicate the claim. Analysis after a similar study showed the presence of anomalous tritium[208], which is expected from normal hot fission. Emission appeared to occur most often when titanium passed through a temperature associated with a phase change. Considerable cracking of the hydride occurred, but noise generated by crack formation did not seem to correlate with neutron emission.

Jones *et al.*[209] have recently detected neutron emission from titanium after it has been reacted with deuterium, similar to the claims made by these workers in the past[210], suggesting hot fusion but not LENR.

3.IV.2. Errors associated with neutron detection

When neutrons pass through $^{10}BF_3$ or ^{3}He gases in a detector, ions are created by the resulting nuclear energy and collected. Because the resulting voltage pulse is small, accidental electrical noise can produce false counts. An energy spectrum can be obtained using NE213[211] or Li-glass scintillation[212] detectors, which detect the gamma ray emitted when a neutron reacts with lithium within the detector. In addition, a small neutron background is always present, requiring large amounts of shielding to make a very small flux visible. [213-215] If the neutron flux is sufficiently great, decay radiation from induced radioactivity in isotopes of certain elements, including silver and gold, can be measured by conventional methods and used to estimate the total number of neutrons collected.(3) A plastic called CR-39 will indicate passage of neutrons as pits formed in the surface that can be made visible by certain treatments. The size, shape, and special relationship between the pits can be used to estimate the kind of particle radiation and its energy, albeit with significant uncertainty. All of the methods have a lower limit, but the CR-39 method is especially sensitive because it can accumulate neutron pits for many days. Occasionally, very large bursts are seen for a brief time during some studies. These bursts are seldom associated with measurable heat or tritium production. Consequently, their source is unknown but unlikely to be caused by LENR. If neutrons were produced at a rate consistent with heat production, all of the methods would be able to provide a very accurate and unambiguous proof for neutron emission, but alas, there is no correlation.

3.V.1. Energetic Photon Radiation

Occasionally, low-energy radiation detectors are placed on or near an active surface either during or after the study. Evidence for low-energy X-rays of various frequencies is sometimes obtained[139, 216-219]. When energy is measured, it can sometimes be attributed to the characteristic k-alpha emission from atoms known to be present. Occasionally, the radiation appears to result from radioactive decay. Evidence for tightly focused beams of radiation has been reported[220] from electrolytic cells as well as during ion bombardment[221]. This behavior is important because it indicates that emitted radiation can be sensitive to the physical orientation of the source, much like a solid-state laser. Particle detectors, such as CR-39 plastic[222-225], placed near an active surface occasionally show evidence for energetic alpha and proton particle emission[226] as well as energetic electrons, although not all from the same sample.

Energy generated from any nuclear reaction must eventually find its way into the surrounding material where it is either converted to heat energy as it is adsorbed or it leaves as energetic emissions that can be detected. Energy released by LENR is obviously absorbed mostly by the apparatus. This is a mixed blessing because it allows studies to be made without danger of radiation exposure, but it makes this diagnostic tool difficult to use.

3.VI.1. Transmutation Products

Recently, and with great difficulty, evidence for nuclear reactions other than fusion is accumulating[227, 228]. These are called transmutation reactions and involve elements much heavier than hydrogen to which hydrogen has been added to their nucleus. Such reactions are found to occur in many environments, including living cells, and when a variety of methods are used. Indeed, the more often these reactions are sought, the more often elements are found in unexpected amounts and/or with abnormal isotopic ratios. Of course, some of the elements result from the unexpected concentration of normally occurring impurities or from simple error. Some proposed reaction products are clearly impossible because energy must be accumulated to account for the mass increase. Nevertheless, some of the observed products appear to be produced by LENR along with energy generation. Some of the isotopes are radioactive but most are not. Most evidence is based on using the electrolytic or gas discharge methods, or a combination thereof. Unexpected elements seem to result from many types of reactions, including fusion involving one or more hydrogen isotopes and a heavy nucleus, fusion between two different heavy nuclei, and fission of a heavy nucleus that normally does not experience this type of reaction. This type of reaction has been very difficult to explain using the mechanisms now (2012) being proposed and difficult to explore because the necessary analytical tools are not widely available and are expensive to use.

Miley et al.[39, 229] have studied this process in some detail using electrolysis of H_2O. A spectrum of nuclear products is found, with high concentrations falling into four mass ranges of 20-30, 50-80, 110-130, and 190-210 [230]. Mizuno *et al.*[13, 231] have also explored the subject in detail using mainly electrolytes based on D_2O. Abnormal isotopic ratios of Hg, Fe and Si were found on the cathode after this study. Although some minor elements might have resulted from contamination, it is very difficult to understand how major concentrations could come from this source, especially those having abnormal isotopic ratios. Many additional reports are available.[1, 227]

A few studies suggest where these reactions form and offer some insight into the process. Compounds dissolved in an electrolyte can deposit their positive constituent on the cathode where it might be converted to another element during electrolysis. For example, when potassium compounds are used in a H_2O-based electrolyte, calcium is formed[80, 81] even though the amount of potassium retained by the surface would be very small. Similar elements suffer the same fate in H_2O[232, 233]. Cathodes made from other metals produce a more complex result[234]. Once again, LENR involves the elements present where the process occurs, which in these examples is at a surface.

A particularly compelling study was reported by Iwamura et al.[45]. They deposited 40 nm of palladium on layers of CaO, which had been deposited on bulk palladium. A small amount of various elements were applied to the surface by electrolysis or vapor deposition. When cesium was used and deuterium gas was caused to diffuse through this sandwich, a reduction in the amount of cesium ($_{55}Cs^{133}$) on the surface was matched by an increase in the amount of praseodymium ($_{59}Pr^{141}$). This reaction requires addition of 4 D to the Cs nucleus. In addition, a small amount of $_{57}La^{137}$ resulting from addition of 2 D was found. This process was followed over a period of time without interruption using

XPS[9] without exposing the surface to the environment. Apparently, transmutation reactions can occur by addition of an even number of deuterons to the target nucleus as a single event. Why were only the deposited elements transmuted rather than the palladium or calcium? This question will be explored in Chapter 6.

Evidence for iron production during arcing between carbon electrodes under H_2O has been reported[37, 38, 235, 236]. This method seems easy to reproduce but can be ambiguous if only a magnet is used to show the presence of iron. Palladium and gold cathodes also showed excessive iron after electrolysis in light water[237, 238].

Radioactive isotopes other than tritium are seldom reported. But when they are, their presence is difficult to reject especially when their half-life and energy can be measured. Because radiation detection is so sensitive, very little of such material needs to be formed for its presence to be very obvious. Nevertheless, caution is required because several radioactive isotopes are normally present in the environment, including potassium, uranium, and radon. Modern detectors reduce this problem by making the source of radiation obvious.

Bush and Eagleton[239] used electrolysis to produce a mixture of radioactive isotopes with an average half-life of 3.8 days. Mizuno et al.[159] found what appeared to be radioactive ^{197}Pt after electromigration of D_2 in a solid oxide. Notoya *et al.*[240] reported evidence for radioactive ^{24}Na in an electrolytic cell containing Na_2CO_3 and H_2O when a Ni cathode was used. Gamma emitters have also found after ion bombardment[241, 242]. Ion bombardment of uranium by hydrogen isotopes caused the emission rate to increase,[243] as also occurred when uranium was electrolyzed in H_2O.[244] It is safe to conclude that radioactive elements might have been produced in other studies as well, but were not detected for lack of trying.

One of the observations most surprising and difficult to explain involves transmutation reactions within living cells. Such claims were made decades ago by Kervran[245], but only recently have the necessary careful measurements been done to give some credibility. Vysotskii *et al.*[68, 246] showed that ^{55}Mn is converted to ^{57}Fe when certain bacteria are grown in D_2O containing $MnSO_4$. Other anomalous nuclear reactions were discovered during later work[71]. Komaki[247, 248] used several types of yeast and bacteria, grown in normal water, to convert elements in their environment to the ones they needed when the required elements were missing. This provides one more unusual condition to be addressed by theory and one more strange observation to test the ability of you, the reader, to remain open-minded.

The information learned so far teaches that LENR is not like hot fusion yet it makes heat and occasional nuclear products, including radioactive isotopes on rare occasions. This can happen in several types of materials using several different methods, all involving relatively low energy. In addition, both D and H can produce heat and nuclear products

[9] Exposure to an X-ray beam causes emission of X-rays produced by the element in question, thereby allowing the kind and amount of the affected element to be determined.

under similar conditions. How can this behavior be explained? First, a basic concept must be introduced and understood.

CHAPTER 4:
Descriptions of the nuclear active environment

This chapter describes a general concept, which if accepted, allows LENR to be discussed and explained more easily. The concept applies to an environment or location in which the mechanism leading to the nuclear reactions must operate. Consequently, it must form before the mechanism can start and it will limit the kinds of proposed mechanism that are plausible. I call this condition the "nuclear active environment" (NAE). In other words, nuclear reactions do not and cannot occur in normal materials, but require formation of a special environment within the material. Understanding and accepting this requirement is basic to accepting what follows.

Identification of the NAE can start by finding a single condition that is present during all successful LENR studies. Requiring consistency with what is known about basic chemical behavior can further limit the nature of this condition. For example, the know rules of chemical behavior limit the kind of processes that can occur in an atomic structure. At the very least, the nuclear mechanism must be compatible with these rules so as not to require chemical or physical changes known not to occur. In other words, the nuclear mechanism cannot operate in isolation without regard to the chemical nature of its environment. The NAE and the nuclear mechanism must work together to cause the proposed nuclear reaction. To do this, the NAE must have a structure that allows energy to operate independently of the surrounding atoms without the limitations normal chemistry applies to energy flow and local accumulation.

LENR is proposed to involve three steps. First the NAE forms, step two involves hydrogen atoms entering the NAE, finally these atoms interact during step three to cause a nuclear reaction. Each of these steps requires a separate and independent description starting with formation of the NAE. No matter how the NAE is formed or its final configuration, the formation process is expected to follow conventional chemical behavior and obey accepted laws governing such processes. Steps one and two must result in reduction of Gibbs Energy and the rate of formation must be controlled by activation energy[10]. In addition, I suspect the process of forming the NAE is endothermic. Obviously, a limit exists to how much NAE can form. Without a limit, power production would increase until the material is destroyed. The reason for this limit must be identified. Application of these requirements can help weed out many impossible

[10] Conventional chemistry uses the relationship ($k = A*e^{-\Delta E/RT}$). This could be applied to LENR if "k", is related to power produced by the nuclear reaction, (T) is the temperature in the NAE, and (ΔE) is the activation energy for forming the NAE or for making H+ (D+) available to the NAE. This assumes an energy barrier exists in all processes that precede the nuclear reaction. If several kinds of nuclear reactions occur at the same time, each could be described by independent equations having the same form, but different activation energies. For example, failure to detect tritium while helium is produced would result partly because the tritium producing reaction would have greater activation energy, hence a lower rate, for the local conditions.

suggestions and help make the process more controllable by identifying the effects of temperature, pressure, and composition on power production.

Once the NAE is formed, the rate at which hydrogen atoms can enter the NAE is determined by the temperature and applied hydrogen (deuterium) pressure. Or stated more exactly, local energy and local hydrogen (deuterium) concentration are the major variables. These variables are expected to cause effects that can be predicted by applying the Laws of Thermodynamics.

Once the NAE is created, how are the variables expected to influence power production? Three major variables are identified for examination.

1. Number of sites where nuclear reactions can occur, i.e. concentration of NAE.
2. Concentration of H or D in the NAE, which is related to the applied H_2 or D_2 pressure.
3. Energy available at the NAE, which is normally provided by temperature. Temperature is expected to have an exponential effect, typical of its effects on ordinary chemical reactions. This energy also can be applied using lasers or other sources.

Each method used to cause LENR is affected by these variables in different ways. For example, the electrolytic method suffers from relatively low temperatures while benefiting from a high concentration of deuterium. In contrast, the gas loading method has low hydrogen concentration while being able to benefit from high temperatures. Both have unknown and highly variable NAE concentrations. The best way to increase the amount of energy would be to maximize all three variables. Consequently, LENR does not necessarily require a high concentration of H or D to function, as is frequently assumed.

Once the NAE forms, the subsequent mechanism operating at the nuclear level may be very unusual, but the researcher has no influence over this reaction. Trying to influence the nuclear process would be like lighting the fuse (creating the NAE) and then trying to control the rate of the resulting explosion. The amount of energy being created locally is simply too large to control once the process starts. Consequently, knowing how this mechanism functions is not important just yet because this knowledge provides no useful ability to make the LENR more reliable. This insight will be put to use in Chapter 6 where a NAE is identified and discussed.

How many kinds of NAE-mechanism combinations are expected? Are all the observed nuclear products created by the same combination? These questions are difficult to answer based on present experience because each method producing LENR involves a different gross chemical environment. Nevertheless, a process so rare and unique would be expected to involve only a small number of different conditions. Some observations give hints about the basic nature of the NAE, starting with the Fleischmann-Pons Effect, as follows.

1. Almost complete loss of helium to the gas.
2. Appearance of tritium in the electrolyte rather than in evolving gas.
3. Transmutation products located only in the surface region.
4. Presence of melted regions on the surface.
5. Ability to generate LENR using thin layers on an inert substrate.

What chemical and physical conditions are present in this location? Many careful analyses of such surfaces reveal a complex alloy containing lithium, platinum, oxygen, elements provided by the Pyrex container, and impurities in the electrolyte, with sometimes no palladium present at all. This impurity layer appears to be necessary to maintain a high concentration of deuterium[119] and perhaps to create the NAE as well. Measurements of the surface composition place it above D/Pd=1.5, as can be seen in Figure 1, which is well above the average composition.[249] In summary, these observations show that the NAE exists only on the surface, it is not pure PdD, and the D/Pd ratio is too great to result from beta-PdD being the only material present. Therefore a model based on the NAE being pure PdD must be rejected.

Deuterium is continuously lost from this layer through cracks, causing a steady but non-uniform flux of deuterons within the layer.[110] Further complicating interpretation, high-resolution SEM examination shows a complicated morphology consisting of dendrites, cracks, well-formed crystal structures with preferred orientation, and a very uneven topology[106, 250-253]. Deposition of palladium using the so-called co-deposition process creates even greater complexity. Just where in this tortured landscape the NAE is located is not known, although it must have a very small size because all features on such a surface are very small. The observed energy is expected to result from the sum of many active sites, with each site acting independently of the others. This kind of behavior can be seen clearly in the IR images taken by Szpak *et al.*[222, 254] showing random flashes as a result of sudden local heating-cooling in random locations. Fogging of photographic film placed against active material shows that tritium is also produced only in random locations very near the surface. Mosier-Boss *et al.*[222] found this effect after electroplating Pd from D_2O, and Sankaranarayanan *et al.*[85] observed the same behavior by loading and deloading Ni wire with H_2. Other studies have produced tritium and detected it using autoradiography, but we cannot be sure LENR is the sole cause when discharge voltages great enough to cause hot fusion[255, 256] are used. From these observations we can conclude that the NAE has a very small size and it is not informally distributed within a complex surface. Presumably, the observed melting can occur where concentration of NAE is especially great.

Arata[257] and Case[43] focused attention on the importance of small particle size. This idea was carried to extreme by attempting to place a few atoms of Pd in the small atomic cage present in Zeolite,[258] but without obvious success. Arata[125, 259] proposed creating nanoparticles of Pd by oxidizing an alloy of Pd+Zr. The dilute Pd-Zr alloy that remains in the final matrix of ZrO_2 appears to produce a small amount of LENR[260, 261], but not enough to identify the small size of the metal particles as being the only important condition. The material Case[43] used, which is a typical chemical catalyst consisting of nanoparticles of Pd on charcoal, does not work unless special carbon is used

and the material is given special treatment. My many attempts to apply finely divided Pd to various materials, including carbon, failed to produce predictable LENR. Obviously, the size of the Pd particles is not the only important variable using this method. After all, any attempt to form nanosized particles will usually create a wide range of sizes, some of which will cause LENR and detectable energy if size were the only important condition. While small size is beneficial, probably because of increased surface area, the total experience shows this is not the only important condition.

Simply causing deuterium to diffuse through palladium or other materials apparently can initiate LENR reactions at a low level. Iwamura *et al.*[262] diffused deuterium through alternate layers of calcium oxide (CaO) and Pd. The presence of CaO was necessary for transmutation to occur on the surface where various elements were deposited. The behavior during this study reveals an even more complex process because the CaO layers were 400Å from the surface where transmutation occurred. Did the CaO create a special species that diffused through the Pd without reacting, only to cause the deposited elements on the surface to transmute? Or did the mechanical and electronic stress introduced by the CaO cause a NAE to form at the surface? In contrast, Liu *et al.* [263] and Biberian and Armanet[264]were able to achieve LENR by simple diffusion of D through pure Pd. Possible features these studies might have in common are described in Chapter 6.

What basic conclusions can be accepted so far? Although the answer is incomplete, a few general conclusions can be provisionally accepted and used to evaluate the suggested mechanisms. These are:

1. LENR does not happen in beta-PdD, but requires formation of a unique NAE before LENR can occur.
2. Formation of the NAE follows rules known to apply to materials.
3. The mechanism causing the nuclear interaction occurs only in the NAE and is closely related to the nature of the NAE.
4. All LENR results from a similar NAE-mechanism combination.
5. This NAE-mechanism combination must be consistent with what is known about the behavior of materials.

These conclusions are applied to the proposed explanations in the next chapter.

CHAPTER 5
Theory

5.I. Introduction

Hundreds of attempts have been made to explain the LENR effect, yet no theory has successfully shown how the effect can be made more reproducible and robust, and no theory has gained acceptance outside of a select group. Nevertheless, a few examples of published explanations will be discussed below to give you an understanding of the approaches being explored and their proposed limitations. Rather than describe each theory, general principles are applied to show how similar approaches can be evaluated.

Two very different assumptions are applied to the process of creating a theory. One approach assumes a spontaneous nuclear reaction can occur within a normal lattice or on the surface of normal material simply because a proposed mechanism starts to operate, usually due to the deuterium concentration reaching a critical level. The other approach, which I'm trying to encourage, assumes a significant and observable change must take place before LENR can occur and this results in a new environment in which the nuclear reactions take place. This unique environment avoids conflicts with how common materials are known to behave and is consistent with just how rare and localized the behavior appears to be, as explained in previous chapters.[11]

The first approach has a basic limitation, as is discussed in the previous chapter, but will be repeated here to emphasize the argument. Ordinary materials are made up atoms arranged in characteristic crystal structures, the form being determined by the energy of electrons associated with the atoms and the thermal energy experienced by the crystals. These energies cannot be altered without changing the structure or, if increased enough, cause melting. The electrons cannot and do not shift spontaneously from one energy level to another in a stable chemical system unless energy is applied from outside the structure or changed conditions make the present structure unstable. Metals such as palladium or nickel and compounds such as PdD are all stable chemical systems under the conditions normally used. Even if a spontaneous change were to take place because of unexpected release of internal energy, the limited magnitude is known not to cause nuclear reactions in common materials.[12] This understanding is so basic, it cannot be ignored without clearly stated and demonstrated reasons. Indeed, the role of energy in materials is so important and well understood that arguments based on quantum mechanics or any proposed increase in energy must be consist with this behavior. Let's see if these requirements have been satisfied when various mechanisms were proposed.

5.II. General Discussion

5.II.1 Role of neutrons

Obviously, if neutrons were involved in the nuclear mechanism, the Coulomb barrier would not be an issue. Therefore, several people have proposed a source of potentially reactive neutrons. These neutrons are thought to be initially present in the material as stable clusters[265] or as stable polyneutrons[266], which are released from this stable condition by some mechanism. No direct evidence exists for trapped neutrons, neither as

[11] As an aside, these two different approaches to finding an explanation reveal a basic difference in how different branches of science look at Nature. People trained in physics focus on mechanisms while trained chemists tend to focus on the environment and conditions. The phenomenon of LENR requires a marriage between these two fields of science, which has not yet happened. Rejection of the observations has generally resulted because a mechanism could not be imagined based on currently accepted "theory". Successful understanding will only happen after the conventional mechanisms are abandoned and a new mechanism is applied to the correct kind of material.

[12] As an example of how a typical material would behave, palladium will melt if more than 0.17 eV is applied to each palladium atom. This amount of local energy is not enough to cause a nuclear reaction. Any energy generating process operating within a lattice of Pd atoms would find that energy accumulation would cease once the local amount had reached this level as bonds were broken and melting commenced. As a result, energy would be absorbed from the proposed energy-accumulating process and the region in which this mechanism operates would be destroyed.

clusters nor as polyneutrons, being present or released in ordinary material. Indeed, if enough neutrons were present to support the large reaction rates being occasionally observed, their presence would be obvious from their effect on the density of such repositories, which has not been found. Also, just how neutrons or polyneutrons would remain in the palladium or any material after chemical purification requires implausible assumptions. Nevertheless, a few observations are consistent with a rare and low-level nuclear process being caused by what might be polyneutrons.

On the other hand, neutrons have been proposed to form[181, 267-269] by fusion of an electron with a proton, which requires 0.76 MeV to be present at the time and place of the reaction. Because this idea has gotten wide attention, it needs to be fully understood. The idea is flawed because it assumes enough energy to form a neutron can be concentrated in a chemical environment at one location. Energy is a real and basic quantity that does not accumulate spontaneously. For this energy to concentrate in an electron or proton, it must be harvested from an environment in which the average energy is much less than 1 eV. Consequently, packets of energy have to spontaneously seek out and add to individual electrons in which the accumulating energy must be stored. How is this accomplished? The electron is a fundamental particle that cannot store energy. If it could, its rest mass would not be constant and the TV would not work. Perhaps energy can be stored by another process. Particles are known to store energy as increased mass if enough energy is added to accelerate them near to the speed of light. Traveling at this speed in a lattice well populated with many electrons and nuclei would seem implausible[13]. So, we are asked to imagine an electron being able to pass through a collection of atoms at near the speed of light while accumulating energy from the surrounding energy fields without losing this energy before a proton is encountered. Calling this a weak interaction, introducing the concept of plasmons, or proposing a super-heavy electron provides no justification for or insight about how the process can actually work.[14] Unless this process can be shown to actually occur, rather than assumed to be possible, formation of a neutron is not plausible as an explanation of LENR. Indeed, when electrons are given the required energy and caused to bombard a material containing p or d, very few, if any, neutrons are detected. In addition, if such a transfer to and concentration of energy in an electron were possible in solid materials, observed chemical effects would be expected long before the electron could make a neutron.

Furthermore, if neutrons were present from any source, radiation from their own normal beta decay and gamma resulting from their interaction with various nuclei would be expected, but is not detected. In addition, the various nuclear products cannot be explained only by neutron interaction because this reaction produces a new isotope, not a new element. Subsequent radioactive decay is required to produce the observed elements,

[13] Electrons of this energy have a very small range in palladium because their energy is lost to the surrounding material by generating X-rays.[271] This means the mysterious transfer of energy must take place at an impossibly fast rate and a proton must be found within a fraction of a micron after this energy has be acquired, all without generating X-rays that are not observed.

[14] Such an abnormal energy distribution conflicts with the well-known Boltzmann distribution and the Second Law of Thermodynamics

which is not observed. Consequently, even though this mechanism has gained some attention, it is not consistent with how LENR behaves or with conventional science.

On the other hand, many people have speculated about what would happen if the electron could get sufficiently close to the nucleus to form what they call a "virtual neutron". In this way, the electron might provide enough shielding for the proton or deuteron to enter a nucleus without the impossible task of creating a real neutron. Mills[270] provides a theoretical basis for allowing the electron to closely approach the nucleus, with the formation of the so-called Hydrino. Dufour *et al.*[271, 272] proposed a structure called a Hydrex where many electrons and photons cluster together in a stable collection that might lower the Coulomb barrier. The formation of Rydberg or BEC structures could be viewed as variations on this approach. Such variations on a pseudo neutron-like structure seem worth exploring. The kind of NAE-mechanism combinations required for such structures to form and be involved in LENR has not been identified, but will be explored in Chapter 6.

5.II.2 Role of phonons

A phonon is a pseudo-particle used to describe how energy is transferred between or interacts with atoms or electrons in condensed matter. This energy exists as vibrations of atoms and electrons located within a material and is related to the temperature. These vibrations are proposed to cause a few atoms to approach one another within nuclear reaction (strong force) distance[273-276] or to cause energy to accumulate within a nucleus[277] so that the nucleus becomes unstable. A basic assumption is made – the vibration energy is focused on one nucleus and does not affect the general chemical bonds between the surrounding atoms. Once a nuclear reaction occurs, phonons are proposed to communicate the released energy to the surrounding atoms. Besides the considerable challenge of showing that phonons have the necessary properties and energy to do the proposed jobs, the logical inconsistency and how interaction with the chemical bonds is avoided need to be explained.

5.II.3 Role of particle-wave conversion

The Chubbs[278] proposed that a deuteron can convert to a wave under proper conditions. As such, it can interact with another deuteron wave without a Coulomb barrier being directly involved. This interaction briefly forms a helium wave, which slowly converts to a helium particle by losing small quanta of energy to the surrounding lattice. This model solves a few problems, but it does not account for how transmutation products are produced or what unique property of the lattice encourages particle-wave conversion. Simply having a periodic array of atoms, as they propose, is not sufficient because this universal condition exists in all materials, while nuclear reactions are rare and localized in special regions. Nevertheless, this general approach could be applied to a special NAE, as discussed in Chapter 6.

5.II.4. Role of "Strange" particles

Explanations based on rare particles have been proposed. These include the Erzion[279] the NATTOH[280], fractionally charged particles[281], massive negative particle[282],

and super-heavy nucleus[266]. While some of these particles obviously exist in Nature, how each might cause the range of behaviors produced by LENR has not been explained.

5.II.5 Role of tunneling or enhanced cross section

The process called "tunneling" is used when a reaction appears to require an abnormally small amount of energy compared to the expected amount. Of course, this idea assumes the full (expected) amount is known accurately for the conditions being used. Instead of using the tunneling metaphor, an unexpectedly large rate is sometimes described as resulting from an increase in cross-section. In either case, the expected energy or cross-section needs to be justified, not just why less energy is apparently required. For example, expected behavior for LENR under various conditions is based on a model obtained using the hot fusion process. The rate of the hot fusion-type reaction is measured as a function of applied energy and the resulting behavior is related to the proposed distance between the deuterium atoms. Application of this approach to LENR would only be valid if LENR were caused by the same mechanism, which is very unlikely to be the case. In addition, the tunneling model does not account for how released energy can be dissipated without producing energetic radiation. Nevertheless, early theoreticians including Preparata[283] and Capek[284] used this approach, followed by many others.

A source of screening electrons has been suggested to exist between two materials having different work functions, the so-called swimming electron theory[285-287]. These electrons are proposed to reduce the Coulomb barrier and explain the transmutation observations reported by Miley[288, 289]. Unfortunately, this theory ignores how the required number of protons can enter the available nuclei in the sample without producing radioactive isotopes, which are seldom detected. Miley *et al.*[290] try to avoid this problem by creating another problem. Their mechanism involves formation of a super-nucleus of $^{306}X_{126}$ from a large cluster of H and D. This structure then experiences various fission reactions. The cluster is proposed to result as local islands of ultra dense hydrogen[292] form by Rydberg-like processes[291] Why so many deuterons would spontaneously form a cluster in a lattice in violation of the Laws of Thermodynamics has not been explained.

5.II.6. Role of multi-body fusion and Bose-Einstein Condensates

Multi-body fusion was first suggested by Takahashi *et al.*[200] who arrived at this model using the energy spectrum of the few neutrons being emitted from an electrolytic cell. Later studies using ion bombardment are consistent with the model [293], which suggest the neutrons might have actually resulted from a hot fusion-type reaction. Iwamura *et al.*[45] show evidence for 4 deuterons entering a nucleus simultaneously, adding additional support to the multi-body model. Formation of such clusters[294] solves many problems, not the least of which is a method to release momentum after fusion without emitting a gamma ray. In this case, energy is deposited in the lattice by several energetic alpha particles and the un-reacted deuterons ejected from the cluster. Such emissions would be obvious[295] unless the cluster were improbably large.

Kim[296, 297] justified cluster formation by calling it a Bose-Einstein Condensate (BEC)[298, 299]. He proposes this type of structure is able to form on the surface of very small particles of PdD. Typically, BEC is only observed near absolute zero because the bonding energy is too small for the structure to survive higher temperatures. Formation of a BEC at the temperatures used to initiate LENR would be an amazing event even without LENR being a consequence.

5.II.7. Theory of Rossi and Piantelli

Piantelli *et al.*,[76-78, 135, 136, 300-305] in a series of papers, has described how energy, radiation, and transmutation results when Ni-Cr tubes are exposed to H_2 after extensive pretreatment. The process is proposed to involve clusters of nickel on the surface that interact with H^- ions dissolved in the metal to cause conversion of nickel to copper when the metal is heated above 350° C. The authors suggest a mechanism and justification for this reaction.

Rossi [137] increased the amount of power over that obtained by Piantelli *et al.* by using specially treated nickel powder and proposed the same source of energy. Furthermore, Rossi[79] believes that positrons result from the decay of the resulting radioactive copper isotopes and these generate annihilation radiation of 0.511 MeV that is absorbed in a lead shield, thereby heating the apparatus. No evidence supports this claim.

The descriptions of the process offered so far can not be considered a theory. The proposed process is not consistent with what is observed nor is it plausible based on the requirements suggested in this Guide. First of all, the NAE is not identified. Second, transmutation cannot be a source of significant energy even if the Coulomb barrier could be overcome. Once a Ni nucleu has been transmuted, energy production can only continue at that site if another H or D is added to the fixed target. Such a process will eventually produce radioactive isotopes, yet these are not found. Furthermore, the amount of energy released by each transmutation reaction is small, requiring a large reaction rate to account for the measured energy[15] as well as many active sites. Explaining how so many sites can form in ordinary material is a challenge not met so far.

CHAPTER 6
A Proposed Explanation of LENR

In the previous chapters, the requirements a theory must satisfy, the behaviors in need of explanation, and the flaws in a few explanations are discussed. The challenge now is to propose a model consistent with these requirements and conditions. The basic assumption, as adopted earlier, is that the same NAE is present regardless of the method or materials used even though different routes can be used to form this universal condition. In addition, this NAE must be compatible with known properties of solid materials. Several examples of plausible NAE have been proposed consisting of Rydberg

[15] The reaction $Ni^{62}+p = Cu^{63}$ produces 5.6 MeV/event. For 1 kW of power to be generated, this reaction must occur at 10^{15} times/sec or produce 8 mg/day of copper. This would result in 15 g of copper after 6 months while producing 10 kW, which would represent a significant and impossible fraction of nickel powder being transmuted during the proposed lifetime of the e-Cat.

matter[306, 307], nanostructures[308-310], diamondoid or Zeolite molecules[311, 312] or cracks[120, 313, 314]. Each occurs within different chemical environments. The NAE might also be where Hydrinos[315] can form. The mechanism operating in each environment must be compatible with that environment. As a result, a complete theory must address a NAE-mechanism combination, not just the NAE or mechanism alone. The general features of a plausible NAE will be used to start the search. The goal is to eliminate most environments by applying these requirements and focus on the few that remain. Environments surviving this process can then be tested against proposed mechanisms to determine which combination is consistent with the most observations.

Four different kinds of environments have been proposed.

(1) A normal arrangement of atoms and electrons that create a crystal structure, so-called bulk atoms. Cubic PdD, either pure or impure, is an example of such an environment.
(2) A novel arrangement of atoms not normally present. The BEC structure, Rydberg matter, and formation of carbon nanotubes are variations of this environment.
(3) An interface between two different structures having different energy or electron concentrations. Examples are two different crystal structures in contact at a surface or contact between two different phases, including contact between a gas and a solid or a liquid and a solid. Because such an environment would be sensitive to the energy and concentration of surface electrons, both could be increased by electrolytic action or by laser radiation applied to an accessible surface.
(4) Absence of material such as cracks, gaps, or voids within structures. Carbon nanotubes or stress cracks in solids would be plausible examples. The dimensions and form of such a structure would determine its behavior.

Involvement of particles having nanosized dimensions has been proposed but this is not considered to be a unique environment in this discussion. Such nanoparticles, at least at the size being used for LENR, differ from ordinary material only because they have a high surface area, which would create a large interface and place them in category (3). If the size is really small (submicron), they no longer act like ordinary material and would fall in category (2).

Each of these proposed locations is evaluated below using the previous categories.

.

(1) Normal material: As explained in Chapter 4, if helium and tritium are created in a regular lattice, the process must take place within a few microns of the cathode surface for their loss from the material to be consistent with observation. However this region is not pure PdD but a complex alloy having properties quite different from PdD. Therefore, any model using the properties of pure PdD is not consistent with reality. Unfortunately, this is not the only flaw created by placing production of LENR in bulk material. As explained in previous chapters, electrons in stable materials are relatively fixed in energy and their relationship to each other is controlled by how the atoms are arranged in the lattice. Any change

sufficient to cause LENR would be expected to conflict with this preexisting structure. This conclusion is based on how materials are known to behave under a wide range of conditions. Why LENR would be an exception needs to be better justified than has been done so far.

(2) Novel material: Growth of a new structure must follow rules that apply to any chemical process. A new structure can only form if the process reduces Gibbs Energy. In addition, the rate of formation will be determined by an activation energy, which if too great will prevent a detectable amount of product from being formed in a reasonable time. Once the material starts to form, the amount will increase at a relatively fixed rate. Consequently, the rate at which LENR occurs, which is determined by the amount of active material, will increase as more of the new structure forms. Unlimited increase is not observed. In fact, rapid formation of the active structure seems to occur until a stable concentration is acquired, which means another process must intervene to limit additional NAE formation. Nevertheless, a runaway reaction might result because temperature is expected to produce positive feedback. An acceptable theory must explain how these processes work, which has not been done so far.

(3) Interface: The amount of energy available at a surface or potential difference created by contact between two materials can be measured using the work function or the over-potential when electrolysis is used. Such measurements do not reveal the presence of enough energy or voltage to directly cause a nuclear reaction. Concentration of energy by a resonance process can be imagined, but this process suffers from the same serious limitation suffered by condition (1), i.e. the amount of local energy would be limited by interaction with the many atoms and electrons in the environment.

(4) Cracks: Most metals form cracks of various sizes when they react with hydrogen as stress is generated by increased lattice size and is then relieved. The number of cracks has a limit determined by the treatment and material. In addition, most materials contain a fixed number of small voids unless great care is taken in their preparation. A crack or void has the potential to act as the site for a resonance process if it has the correct size, contains hydrogen atoms, and is closed at both ends. Early suggestions for cracks being the NAE were ignored because crack formation in PdD would allow D_2 to escape from an electrolyzing cathode, thereby reducing the D/Pd ratio and the rate of LENR. This problem does not apply to the gas loading method and perhaps not to all cracks formed on an electrode.

Given all the observations and requirements, what feature is common to all? The only universal features are cracks, gaps, or nanotube-type structures, as several people have already proposed.[314, 316-318] While this environment is located within a normal chemical structure, it can be proposed to support reactions that do not interact with the surrounding atoms and that would not be limited to the energy density imposed by a normal lattice. What mechanism can operate in such an environment to cause each kind of nuclear reaction and what would be the result? A search for the answer is described in the next section.

6.I. Proposed Process Causing LENR

For a search to be successful, it must follow a series of perhaps ambiguous clues in the correct logical order. The first clue in this search involves tritium and how it can form. Because it apparently forms in the same region of the material as does helium and no detectable radiation typical of hot fusion is produced, tritium and helium can be assumed to result from the same general mechanism and NAE. Since the hot fusion process is ruled out and tritium seems to be produced when both H and D are present, the logical source would be fusion involving H and D. But this reaction gives He^3 as first proposed in 1990 by Schwinger[321]. Such direct formation can be ruled out because the amount of detected He^3 is only consistent with that expected to result from decay of tritium, which means tritium is formed before He^3. Tritium can form only if an electron is absorbed into the fusion reaction and is subsequently ejected by normal beta decay. If electron absorption is universal regardless of the isotopes involved, then the reactions listed in Table 3 can be predicted. In every case except tritium, ejection of the electron from the product nucleus would be too rapid to measure. In addition, like tritium, the

TABLE 3

Predicted nuclear reactions involving isotopes of hydrogen

$D+D+e=H^4=He^4+e$	Q=<23.8 MeV
$D+H+e=T=He^3+e$ (18.6keV)	Q=4.9 MeV (T=tritium=H^3)
H+H+e=D	Q=1.4 MeV
$D+T+e=H^5=He^4+n+e$	Q=<18.1 MeV
$H+T+e=H^4=He^4+e$	Q=<20.4 MeV

energy of this beta would be too low to allow easy detection. In fact, were it not for the slow rate of tritium decay, this proposed addition of an electron could not be observed and might be ignored. By accepting this clue, a general pattern for the fusion reaction can be suggested that makes many observations much easier to understand. In addition, a proposed mechanism can be evaluated because it must be able to add this electron by a plausible process during the fusion reaction.

Before going to the next clue, let's see if the proposed process helps explain observed behavior. First, the presence of a few neutrons when tritium is produced now makes sense. As tritium accumulates, T+D+e fusion can occur, resulting in the very small but variable flux of neutrons. Support for this reaction is given by Mosier-Boss *et al.*[203] using CR-39 detectors. Second, the expected energy from each reaction (Q) can be used to explain some behavior.[16] Note that energy from the H+H+e fusion reaction is much smaller than from the D+D+e reaction. Consequently, the former reaction would require many more NAE sites to achieve the same amount of detected power compared to when deuterium is used, thereby making the D+D+e reaction easier to detect. Consequently, failure to detect heat when hydrogen is used as a null test means only that too little NAE was present to make detectable energy. In this way, the claims for extra power made by Fleischmann and Pons during their null tests using H_2O can be understood. Furthermore,

[16] The effect of neutrino formation when an electron is added and ejected is ignored. Nevertheless, this would reduce the amount of measured energy by some unknown amount because energy added to the neutrino would not be converted to measured heat.

light water apparently acts as a poison simply by reducing the amount of power compared to when D_2O is used, not by stopping LENR altogether. Third, the weak beta emission could produce the occasionally reported low-level Bremsstrahlung. This one clue opens a window onto a broad view of the process and allows some other clues to be seen.

What kind of mechanism and NAE would be consistent with tritium production? To avoid detectable emission, the energy released by the nuclear reaction must either involve many atoms that are emitted from the site, with each carrying a small fraction of the energy – or the energy must be released over a period of time with many photons (X-ray) or phonons dissipating energy to the surrounding atoms. The first possibility requires a large collection of atoms too implausible to justify. On the other hand, a resonance process can produce a slow release of energy. This process can be imagined to involve nuclei of hydrogen (Table 3) with a shielding electron between each that gets sucked into the final product. Obviously, the relationship between the nuclei and the intervening electron is not conventional. Sinha and Meulenberg[319] proposed a structure, called a Lochon, that might apply. Kim and Ward[320] propose a resonance process between deuterons in a BEC when it forms on the surface of a nanoparticle of PdD. A crack or nanotube also might support a resonance process, but in this case along its axis. Once this string of nuclei and electrons starts to resonate, the mass of contained nuclei and dimensions of the structure are expected to determine the frequency of emitted photons. As a result, photons (X-rays) would be generated as mass converts to energy and the distance between the nuclei approaches that required for the strong force to complete the fusion process. Although details of this proposed process are not examined here, Table 3 summarizes the expected nuclear products and a list of testable predictions is provided in the next section.

What evidence can be offered to support this speculation? First, can cracks form in the materials being used? PdD is well known to form cracks[322, 323]. Titanium, another successful metal, cracks readily when it reacts with hydrogen. When this metal is used as the cathode during electrolysis of D_2O, extra energy and transmutation are reported[324-328]. In addition, neutrons[329-331] are emitted when it is temperature cycled in D_2, further indicating active crack formation. Nickel does not form cracks easily when exposed to hydrogen, but thermal or pressure cycling in hydrogen[136, 300] is expected to produce some cracks in the surface. The oxides that produce LENR by electromigration[51, 52, 158] all have the Perovskite crystal structure. This structure is susceptible to distortions as a result of small changes in component atom concentrations that could cause local cracks. The slight flow of hydrogen caused by applied voltage would move hydrogen atoms to these locations. Layers of palladium applied to various materials, as used by Patterson[332] and later by Miley[229, 291], are observed to crack when reacted with hydrogen. Layers containing possible cracks have also been applied to wires by Celani *et al.*[333]. In this case, creating a flux using flowing current enhanced the process perhaps by making deuterons more readily available to proposed cracks. Sonofusion[334] would be expected to cause cracks at the site of bubble collapse on a target metal. In addition, to cracks formed as a result of stress, all materials are known to contain imperfections unless efforts are made to remove them. While a large number of active cracks would produce obvious power, the small number in ordinary material might

result in detectable amounts of LENR if hydrogen ions were available and careful measurements were made. Nanotubes are expected to be more difficult to make, but might be present and occasionally active.

Another behavior consistent with cracks being the NAE is observed on occasion. Placement of X-ray sensitive film near an active electrolytic cell has shown X-radiation having a very narrow beam width.[220, 335] Gas discharge has also produced similarly tightly focused X-rays that act like a laser.[144, 336] Such behavior requires emission only in favored directions, which requires a special structure. For example, small structures similar to cracks have been observed to produce laser emission.[337] Failure to detect radiation could result when most X-radiation is completely absorbed, or because most beams are pointed away from the detectors. A diffuse source could be produced when many cracks were pointed in random directions. Consequently, laser-like radiation would be rare and only observed when detectors are in the right place or the sources are all pointed in the same direction.

The study by Iwamura *et al.*[338] provides an opportunity to test the role of cracks in explaining transmutation. As explained previously, these workers deposited CaO+Pd layers on palladium, which was over-coated by 40 nm of palladium, after which various elements were applied to the surface. When deuterium diffused through this sandwich, the deposited nuclei were transmuted by addition of deuterons. Amazingly, only the deposited nuclei experienced transmutation, not the much larger concentration of palladium also present on the surface. In addition, the CaO layer was found to be essential for the process to work. This behavior can be explained if stress-cracks formed in the thin palladium layer between the CaO and the surface where the target element was deposited. In the process, the deposited material filled the mouths of the cracks, thereby sealing them and creating a cavity in which deuterons could accumulate and resonate. This resonance process is proposed to release energy and cause deuterons to enter those nuclei located at the end of the cavity, i.e. the deposited target. Only nuclei present at this exact location can be transmuted according to this model. Further support is provided by Patterson who produced many cracks when he coated plastic beads with layers of Pd and/or Ni. Many transmutated elements were found in the layers by Miley.

The claim for nuclear reactions being possible in bacteria and other single-cell organisms is a challenge for any explanation. Obviously, the chemical conditions are greatly different from these within inorganic crystals and the mechanisms applied to such crystal structures would not be expected to apply to a living cell. On the other hand, existence of voids created by complex protein molecules can be imagined to form in which the proposed resonance might take place provided hydrogen ions are available to the void. While this assumption has no evidence as yet, the suggestion can be tested.

Obviously, the thickness of the crack would be important because at some width, the normal hydrogen molecule is known to form, which is not able to fuse. The difficulty in causing LENR would be related to formation of a closed crack of exactly the right dimension that can be populated with enough D or H atoms. Naturally, these requirements would be very sensitive to applied conditions and treatment.

No single observation provides a smoking gun. Nevertheless, a total analysis of all observations leads to one plausible conclusion – cracks or nanotubes of a particular size and shape is the only NAE that does not result in conflict with the known behavior of materials, allows a plausible mechanism to operate, and leads to many testable predictions, many of which are consistent with behavior already observed. The puzzle still lacks a clear description of the mechanism operating within the crack. Once a mechanism is found to apply, mathematical analysis can be used to further support the model and generate other predictions.

6.II Testable Predictions

The model suggests the following testable predictions as a guide to future studies.

1. X-ray radiation would be produced at a wavelength determined partly by the length of the crack and it would tend to be emitted in opposite directions among the axis of the crack. Some of this radiation would appear to result from Bremsstrahlung
2. Rate of tritium production would be sensitive to the H/D ratio in the NAE.
3. Rate of neutron production would be sensitive to the D/T ratio in the NAE.
4. Energy production from normal hydrogen would result first in production of deuterium and then tritium, followed by a small but increasing neutron flux.
5. Diffusion of H or D through a material containing suitable NAE could cause detectable LENR because H or D would become available at the NAE. Increased applied pressure of D_2 or H_2 would have the same effect.
6. Laser light would increase the rate of LENR as energy is added to the resonance process. Increased temperature would have the same effect, but would not be as localized.
7. Transmutation would be experienced by nuclei located at the ends of active cracks or nanotubes.
8. LENR using deuterium would gradually slow down as active NAE sites became choked by immobile helium. This lifetime limiting process would be much slower when H is used because D and T can move out of the NAE or enter into subsequent fusion reactions. Nevertheless, the growing concentration of D will increase the activation energy for resonance, thereby reducing its rate, and produce trapped helium.
9. No difference exists between the conditions required to cause fusion involving pure D or pure H. However, many more NAE sites are required to obtain a detectable amount of energy when H is used compared to D.
10. A mixture of D and H in a NAE makes LENR more difficult to start (increased activation energy) because the mixture, consisting of different masses, disrupts resonance. Apparent "poisoning" of the reaction is the result. Adding energy at the location of the crack can reduce the effect of this disruption.
11. A material producing significant power will self-heat and reach a stable temperature determined by how effectively hydrogen can reach the NAE at

that temperature. The greater the amount of NAE, the higher this temperature limit will be.

12. Any metal or alloy able to catalyze decomposition of the hydrogen molecule into ions will support LENR once the NAE forms.

SUMMARY

Two assumptions are made: All LENR occurs in the same environment and by the same mechanism, and the environment and mechanism must not conflict with known chemical behavior or each other. Elimination of all environments that conflict with these assumptions and identification of the only environment common to all methods for producing LENR results in the following conclusions:

1. A special environment is required for LENR to occur and this is not a material such as PdD or NiH, regardless of its purity, dimension, or hydrogen content.
2. A closed crack, void or gap of critical size and shape is the only condition potentially common to all methods for causing LENR. This gap may have the form of a nanotube made from various materials including carbon.
3. The mechanism for lowering the Coulomb barrier involves a single electron that is absorbed by the fusion process and remains for a short time in the resulting product, after which it is emitted as a weak beta.
4. The fusion process results from resonance, which releases the resulting energy as X-rays over a short period of time.
5. All isotopes of hydrogen can produce LENR, which results in fusion and transmutation.
6. Heat is mostly generated by D+D+e fusion to give He^4+e when deuterium is used and H+H+e fusion to give stable deuterium when normal hydrogen is used. When both isotopes are present, tritium is formed by the D+H+e fusion reaction.
7. LENR occasionally involves addition of hydrogen isotopes to heavy nuclei, resulting in transmutation at an active site. This reaction does not absorb an electron.
8. Detectable radiation and radioactive isotopes are occasionally produced, but are not common.
9. Several nuclear mechanisms besides LENR can operate within solid materials. These are sensitive to the chemical conditions, including hot fusion-type reactions when applied energy is low.
10. Successful theory requires a marriage between physics and chemistry, and a compatible relationship between the NAE and the mechanism operating within the NAE.
11. Unreasonable skepticism and rejection of competent observation has severely handicapped the field and delayed understanding and application.

Some of these conclusions are significantly different from conventional beliefs in the field and are well outside of what conventional physics can presently explain or justify. As a student, your job is to decide which assumptions and conclusions are correct based on past and future studies. The conclusions are offered as a guide to future studies.

COMMENT

Science has been successful because certain rules of evidence were adopted centuries ago, the so-called Scientific Method. These rules require that many people using different devices duplicate all novel observations. Such replications reduce the human tendency to deceive and to be deceived. In addition, the behavior observed in these various studies must show similar patterns, i.e. important variables must have the same effect in all studies, regardless of the equipment used. Having an explanation for a strange behavior is NOT initially necessary, although eventual discovery of an explanation is important. This is a good method and has served mankind well when it is faithfully applied. Science fails when these rules are ignored. They can be ignored several different ways, the most obvious being premature acceptance. Some scientists think premature acceptance is so damaging that they base their careers on protecting Science from such a violation. A less obvious problem occurs when evidence is ignored because a scientist does not WANT to believe results that conflict with a favorite theory. Initially, cold fusion was rejected for the former reason. Now rejection is based on the latter. The first rejection was valid and consistent with the Scientific Method. The present rejection is not.

Skepticism, when carried to extreme, is as damaging as naive acceptance. At the present time, many people respect the skeptic for guarding the high ideals of science. Unfortunately, skeptics frequently cause much more harm by stopping progress, stifling originality, and turning creative people away from science altogether. Although many examples of this injury can be cited from many fields of science, the continued rejection of LENR is particularly egregious because of its vehement nature and the importance of the discovery. I ask you, the reader, to use good judgment and a responsible attitude in evaluating the novel claims described in this Guide. Remember that new and strange claims do not have to be blindly accepted or blindly rejected, but only explored with an open mind. Important new ideas always conflict with conventional understanding. Such conflict should not be used as a basis for outright rejection before the possibilities have been carefully examined.

Skeptics often point to failures as a way to reject the process. Actually a failure in one laboratory seldom casts doubt on work in another, unless the two use exactly the same instruments and techniques, which is seldom the case. Failure has many fathers besides the claim being false.

Acknowledgements

I wish to thank Jed Rothwell and Ruby Carat for applying their editing skills to some of the more tortured sentences. The mechanism originated by Brian Scanlan, my collaborator in the field for many years, helped show where to look for the NAE. Without his theoretical creation of an original mechanism, the search for the NAE would have been much more difficult. Discussions with Abd ul-Rahman Lomax helped me make the arguments and speculations more focused.

References

1. Storms, E.K., *The science of low energy nuclear reaction*. 2007, Singapore: World Scientific. 312.
2. Rothwell, J., *Cold fusion and the future*. 2007: www.LENR.org.
3. Sheldon, E., *An overview of almost 20 years' research on cold fusion*. Contemp. Phys., 2009. **49**(5): p. 375.
4. Krivit, S.B. and N. Winocur, *The rebirth of cold fusion; Real science, real hope, real energy*. 2004, Los Angeles, CA: Pacific Oaks Press.
5. Simon, B., *Undead science: Science studies and the afterlife of cold fusion*. 2002, New Brunswick, NJ: Rutgers University Press. 252.
6. Close, F., *Too hot to handle. The race for cold fusion*. second ed. 1992, New York: Penguin, paperback.
7. Mallove, E., *Fire from ice*. 1991, NY: John Wiley.
8. Peat, F.D., *Cold fusion: The making of a scientific controversy*. 1989, Chicago: Contempory Books. 188.
9. Park, R., *Voodoo science*. 2000, New York, NY: Oxford University Press. 211 pages.
10. Taubes, G., *Bad science. The short life and weird times of cold fusion*. 1993, NY: Random House. 503.
11. Huizenga, J.R., *Cold fusion: The scientific fiasco of the century*. second ed. 1993, New York: Oxford University Press. 319.
12. Kozima, H., *The science of the cold fusion phenomenon*. 2006: Elsevier Science. 208.
13. Mizuno, T., *Nuclear transmutation: The reality of cold fusion*. 1998, Concord, NH: Infinite Energy Press. 151.
14. Beaudette, C.G., *Excess heat. Why cold fusion research prevailed*. 2000, Concord, NH: Oak Grove Press (Infinite Energy, Distributor). 365 pages.
15. Paneth, F. and K. Peters, *On the transmutation of hydrogen to helium*. Naturwiss., 1926. **43**: p. 956 (in German).
16. Clery, D., *ITER's $12 billion gamble*. Science, 2006. **214**(5797): p. 238.
17. Cho, A., *Bigger contributon to ITER erodes domestic fusion program*. Science, 2012. **335**: p. 901-902.
18. Fleischmann, M., S. Pons, and M. Hawkins, *Electrochemically induced nuclear fusion of deuterium*. J. Electroanal. Chem., 1989. **261**: p. 301-308 and errata in Vol. 263, 187-188.
19. Jones, S.E., *et al*., *Observation of cold nuclear fusion in condensed matter*. Nature (London), 1989. **338**: p. 737.
20. Jiang, S., J. Liu, and M. Hea, *A possible in-situ 3H and 3He source in Earth's interior: an alternative explanation of origin of 3He in deep Earth*. Naturwiss., 2010. **97**(7): p. 655-662.
21. Storms, E.K., *The status of cold fusion (2010)*. Naturwissenschaften, 2010. **97**: p. 861.
22. Santandrea, R.P. and R.G. Behrens, *A review of the thermodynamics and phase relationships in the palladium- hydrogen, palladium-deuterium and palladium-tritium systems*. High Temperature Materials and Processes, 1986. **7**: p. 149.
23. Storms, E. *Excess power production from platinum cathodes using the Pons-Fleischmann effect*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 55-61.
24. Warner, J., J. Dash, and S. Frantz. *Electrolysis of D_2O with titanium cathodes: enhancement of excess heat and further evidence of possible transmutation*. in *The Ninth International Conference on Cold Fusion*. 2002. Beijing, China: Tsinghua University: Tsinghua University. p. 404.
25. Bush, R.T. and R.D. Eagleton. *Calorimetric studies for several light water electrolytic cells with nickel fibrex cathodes and electrolytes with alkali salts of potassium, rubidium, and cesium*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 13.
26. Mills, R.L. and P. Kneizys, *Excess heat production by the electrolysis of an aqueous potassium carbonate electrolyte and the implications for cold fusion*. Fusion Technol., 1991. **20**: p. 65.
27. Fleischmann, M. and S. Pons, *Calorimetry of the Pd-D_2O system: from simplicity via complications to simplicity*. Phys. Lett. A, 1993. **176**: p. 118.
28. Lonchampt, G., *et al*. *Excess heat measurement with Pons and Fleischmann Type cells*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 202.
29. Mengoli, G., *et al*., *Calorimetry close to the boiling temperature of the D_2O/Pd electrolytic system*. J. Electroanal. Chem., 1998. **444**: p. 155.
30. Bockris, J.O.M., *et al*., *Triggering of heat and sub-surface changes in Pd-D systems*. Trans. Fusion Technol., 1994. **26**(#4T): p. 267.
31. Letts, D. and D. Cravens. *Laser stimulation of deuterated palladium: past and present*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 159.
32. Violante, V., *et al*. *Progress in excess power production by laser triggering*. in *Condensed Matter Nuclear Science, ICCF-12*. 2005. Yokohama, Japan: World Scientific. p. 55.

33. Nassisi, V., *Transmutation of elements in saturated palladium hydrides by an XeCl excimer laser*. Fusion Technol., 1998. **33**: p. 468.
34. Castellano, *et al*. *Nuclear transmutation in deutered Pd films irradiated by an UV laser*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 287.
35. Mizuno, T., *et al*., *Production of heat during plasma electrolysis*. Jpn. J. Appl. Phys. A, 2000. **39**: p. 6055.
36. Ohmori, T. and T. Mizuno, *Nuclear transmutation reaction caused by light water electrolysis on tungsten cathode under incandescent conditions*. Infinite Energy, 1999. **5**(27): p. 34.
37. Ransford, H.E., *Non-Stellar nucleosynthesis: Transition metal production by DC plasma-discharge electrolysis using carbon electrodes in a non-metallic cell*. Infinite Energy, 1999. **4**(23): p. 16.
38. Sundaresan, R. and J.O.M. Bockris, *Anomalous reactions during arcing between carbon rods in water*. Fusion Technol., 1994. **26**: p. 261.
39. Miley, G. and P. Shrestha, *Transmutation reactions and associated low-energy nuclear reactions effects in solids*, in *ACS Symposium Series 998, Low-Energy Nuclear Reactions Sourcebook*, J. Marwan and S.B. Krivit, Editors. 2008, American Chemical Society: Washington, DC. p. 173-218.
40. Lipson, A.G., *et al*. *In-situ charged particles and X-ray detection in Pd thin film-cathodes during electrolysis in $L_{i2}SO_4/H_2O$*. in *The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science*. 2002. Tsinghua Univ., Beijing, China: Tsinghua Univ. Press. p. 218.
41. Storms, E., *Ways to initiate a nuclear reaction in solid environments*. Infinite Energy, 2002. **8**(45): p. 45.
42. Arata, Y. and Y.-C. Zhang, *The basics of nuclear fusion reactor using solid pycnodeuterium as nuclear fuel*. High Temp. Soc, Japan, 2003. **29**: p. 1.
43. Case, L.C. *Catalytic fusion of deuterium into helium-4*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 48.
44. McKubre, M.C.H., *et al*. *The emergence of a coherent explanation for anomalies observed in D/Pd and H/Pd system: evidence for ^4He and ^3He production*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 3-10.
45. Iwamura, Y., *et al*., *Observation of Low Energy Nuclear Transmutation Reactions Induced by Deuterium Permeation through Multilayer Pd and CaO thin Film*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 132-144.
46. Liu, B., *et al*. "*Excess heat*" *induced by deuterium flux in palladium film*. in *Condensed Matter Nuclear Science, ICCF-12*. 2005. Yokohama, Japan: World Scientific. p. 75.
47. Biberian, J.-P. and N. Armanet. *Excess heat during diffusion of deuterium through palladium*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 170.
48. Claytor, T.N., *et al*. *Tritium production from palladium alloys*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 88-93.
49. Dufour, J., *et al*., *Interaction of palladium/hydrogen and palladium/deuterium to measure the excess energy per atom for each isotope*. Fusion Technol., 1997. **31**: p. 198.
50. Mizuno, T., *et al*., *Anomalous heat evolution from a solid-state electrolyte under alternating current in high-temperature D_2 gas*. Fusion Technol., 1996. **29**: p. 385.
51. Oriani, R.A., *An investigation of anomalous thermal power generation from a proton-conducting oxide*. Fusion Technol., 1996. **30**: p. 281.
52. Biberian, J.-P., *et al*. *Electrolysis of $LaAlO_3$ single crystals and ceramics in a deuteriated atmosphere*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 27.
53. Botta, E., *et al*. *Search for ^4He production from Pd/D_2 systems in gas phase*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 233-240.
54. Celani, F., *et al*., *The effect of γ–β phase on H(D)/Pd overloading*. 1998, Laboratori Nazionalidi Frascati.
55. Bartolomeo, C., *et al*. *Alfred Coehn and after: The alpha, beta and gamma of the palladium-hydrogen system*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 19.
56. Stringham, R. *Sonofusion Produces Tritium That Decays to Helium Three*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 57-60.
57. Jorné, J., *Ultrasonic irradiation of deuterium-loaded palladium particles suspended in heavy water*. Fusion Technol., 1996. **29**: p. 83.
58. Lipson, A.G., *et al*., *The generation of nuclear fusion products by a combination of cavitation action and electrolysis at the titanioum surface in deuterated electrolyte*. Zh. Tekh. Fiz., 1993. **63**(7): p. 187 (in Russian).
59. Petrucci, A., R. Mignani, and F. Cardone. *Comparison Between Piezonuclear Reactions and CMNS Phenomenology*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 246-250.
60. Griggs, J.L. *A brief introduction to the hydrosonic pump and the associated "excess energy" phenomenon*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 43.

61. Taleyarkhan, R.P., *et al*., *Evidence for nuclear emissions during acoustic cavation*. Science, 2002. **295**: p. 1868.
62. Toriyabe, Y., E. Yoshida, and J. Kasagi. *Li+D and D+D Fusion Assisted with Acoustic Cavitation*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 257-262.
63. Arzhannikov, A.V. and G.Y. Kezerashvili, *First observation of neutron emission from chemical reactions*. Phys. Lett., 1991. **A156**: p. 514.
64. Beltyukov, I.L., *et al*., *Laser-induced cold nuclear fusion in Ti-H_2-D_2-T_2 compositions*. Fusion Technol., 1991. **20**: p. 234.
65. Menlove, H.O., *et al*., *The measurement of neutron emission from Ti plus D2 gas*. J. Fusion Energy, 1990. **9**: p. 215.
66. Scaramuzzi, F. *Survey of gas loading experiments*. in *Second Annual Conference on Cold Fusion, "The Science of Cold Fusion"*. 1991. Como, Italy: Societa Italiana di Fisica, Bologna, Italy. p. 445.
67. Jones, S.E., *et al*. *In quest of a trigger mechanism for neutron emissions from deuterium/solid systems*. in *Anomalous Nuclear Effects in Deuterium/Solid Systems, "AIP Conference Proceedings 228"*. 1990. Brigham Young Univ., Provo, UT: American Institute of Physics, New York. p. 206.
68. Vysotskii, V. and A.A. Kornilova, *Low-energy Nuclear Reactions and Transmutation of Stable and Radioactive Isotopes in Growing Biological Systems*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 146-160.
69. Komaki, H. *An Approach to the Probable Mechanism of the Non-Radioactive Biological Cold Fusion or So-Called Kervran Effect (Part 2)*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 44-1 to 44-12.
70. Kervran, C.L., *Biological transmutation*. 1980: Beekman Publishers, Inc.
71. Vysotskii, V., A.B. Tashyrev, and A.A. Kornilova, *Experimental observation and modeling of Cs-137 isotope deactivation and stable isotope transmutation in biological cells*, in *ACS Symposium Series 998, Low-Energy Nuclear Reactions Sourcebook*, J. Marwan and S.B. Krivit, Editors. 2008, American Chemical Society: Washington, DC. p. 295-309.
72. Reifenschweiler, O., *About the possibility of decreased radioactivity of heavy nuclei*. Fusion Technol., 1997. **31**: p. 291.
73. Tsyganov, E.N., *Cold nuclear fusion*. Phys. Atomic Nuclei, 2011. **75**(2): p. 153-159.
74. Huke, A., *et al*. *Evidence for a target-material dependence of the neutron-proton branching ratio in d+d reactions for deuterium energies below 20 kev*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, Franc: World Scientific Co. p. 210.
75. Czerski, K., *et al*., *The 2H(d,p)3H reaction in metallic media at very low energies*. Europhys. Lett., 2004. **68**: p. 363.
76. Campari, E.G., *et al*. *Ni-H systems*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 69.
77. Focardi, S., R. Habel, and F. Piantelli, *Anomalous heat production in Ni-H systems*. Nuovo Cimento, 1994. **107A**: p. 163.
78. Focardi, S., *et al*. *Evidence of electromagnetic radiation from Ni-H systems*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, France: World Scientific Co. p. 70.
79. Rossi, A., *Method and apparatus for carrying out nickel and hydrogen exothermal reaction*. 2011: USA.
80. Bush, R.T., *A light water excess heat reaction suggests that 'cold fusion' may be 'alkali-hydrogen fusion'*. Fusion Technol., 1992. **22**: p. 301.
81. Notoya, R. and M. Enyo. *Excess heat production in electrolysis of potassium carbonate solution with nickel electrodes*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 421.
82. Notoya, R., T. Ohnishi, and Y. Noya, *Nuclear reactions caused by electrolysis in light and heavy water solutions*. J. New Energy, 1996. **1**(4): p. 40.
83. Bush, R.T., *Electrolytic stimulated cold nuclear synthesis of strontium from rubidium*. J. New Energy, 1996. **1**: p. 28.
84. Savvatimova, I., Y. Kucherov, and A. Karabut, *Cathode material change after deuterium glow discharge experiments*. Trans. Fusion Technol., 1994. **26**(4T): p. 389-394.
85. Sankaranarayanan, T.K., *et al*. *Evidence for tritium generation in self-heated nickel wires subjected to hydrogen gas absorption/desorption cycles*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 173.
86. Czerwinski, A., *Influence of lithium cations on hydrogen and deuterium electrosorption in palladium*. Electrochim. Acta, 1994. **39**: p. 431.
87. Silver, D.S., J. Dash, and P.S. Keefe, *Surface topography of a palladium cathode after electrolysis in heavy water*. Fusion Technol., 1993. **24**: p. 423.
88. Miyamoto, S., *et al*. *Movement of Li during electrolysis of 0.1M-LiOD/D_2O solution*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 28.

89. Lihn, C.J., *et al*., *The influence of deposits on palladium cathodes in D_2O electrolysis*. Fusion Technol., 1993. **24**: p. 324.
90. Storms, E.K. and T.W. Grimshaw, *Judging the Validity of the Fleischmann–Pons Effect*. J. Cond. Matter Nucl. Sci., 2010. **3**: p. 9-30.
91. Storms, E.K., *Description of a dual calorimeter*. Infinite Energy, 2000. **6**(34): p. 22.
92. Miles, M.H. and K.B. Johnson. *Improved, open cell, heat conduction, isoperibolic calorimetry*. in *Sixth International Conference on Cold Fusion,Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 496.
93. Miles, M. and M. Fleischmann, *Measurements of Excess Power Effects In Pd/D2O Systems Using a New Isoperibolic Calorimeter*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 45-55.
94. Belzner, A., *et al*., *Two fast mixed-conductor systems: deuterium and hydrogen in palladium - thermal measurements and experimental considerations*. J. Fusion Energy, 1990. **9**(2): p. 219.
95. McKubre, M.C. and F. Tanzella. *Mass Flow Calorimetry*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington DC. p. 32-46.
96. D'Aulerio, L., *et al. Thermal analysis of calorimetric systems*. in *Condensed Matter Nuclear Science, ICCF-12*. 2005. Yokohama, Japan: World Scientific. p. 145.
97. Storms, E.K. *How to make a cheap and effective Seebeck calorimeter*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 269.
98. Storms, E., *Description of a Seebeck calorimeter*. 2005: www.LENR.org.
99. Letts, D., *Codeposition Methods: A Search for Enabling Factors*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 81-92.
100. Hansen, W.N. *Report to the Utah State Fusion/Energy Council on the analysis of selected Pons Fleischmann calorimetric data*. in *Second Annual Conference on Cold Fusion, "The Science of Cold Fusion"*. 1991. Como, Italy: Societa Italiana di Fisica, Bologna, Italy. p. 491-527.
101. Wilson, R.H., *et al*., *Analysis of experiments on the calorimetry of LiOD-D_2O electrochemical cells*. J. Electroanal. Chem., 1992. **332**: p. 1.
102. Storms, E., *A critical evaluation of the Pons-Fleischmann effect: Part 1*. Infinite Energy, 2000. **6**(31): p. 10.
103. Miles, M.H., M.A. Imam, and M. Fleischmann, *Calorimetric analysis of a heavy water electrolysis experiment using a Pd-B alloy cathode*. Proc. Electrochem. Soc., 2001. **2001**(23): p. 194.
104. Storms, E., *The nature of the nuclear-active-environment required for low energy nuclear reactions*. Infinite Energy, 2002. **8**(45): p. 32.
105. Brillas, E., *et al*., *Product analysis from D_2O electrolysis with Pd and Ti cathodes*. Electrochim. Acta, 1992. **37**(2): p. 215.
106. Zhang, W.-S. and J. Dash. *Excess heat reproducibility and evidence of anomalous elements after electrolysis in Pd/D_2O+H_2SO_4 electrolystic cells*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 202.
107. McKubre, M.C.H., *et al. Excess power observations in electrochemical studies of the D/Pd system; the influence of loading*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 5.
108. Oya, Y., *et al. Material conditions to replicate the generation of excess energy and the emission of excess neutrons*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 285.
109. Storms, E., *My life with cold fusion as a reluctant mistress*. Infinite Energy, 1999. **4**(24): p. 42.
110. McKubre, M.C.H., *et al. Concerning reproducibility of excess power production.* in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 17.
111. Dardik, I. *SuperWaves™ as the Natural Origin of Excess Heat*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 307-311.
112. Miles, M.H. *The extraction of information from an integrating open calorimeter in Fleischmann-Pons effect experiments*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 97.
113. Mosier-Boss, P.A., *et al*., *Use of CR-39 in Pd/D co-deposition experiments*. Eur. Phys. J. Appl. Phys., 2007. **40**: p. 293-303.
114. Szpak, S., *et al*., *Thermal behavior of polarized Pd/D electrodes prepared by co-deposition*. Thermochim. Acta, 2004. **410**: p. 101.
115. Lonchampt, G., L. Bonnetain, and P. Hieter. *Reproduction of Fleischmann and Pons experiments*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 113.
116. Miles, M., *et al. The elevation of boiling points in H_2O and D_2O electrolytes.* in *The Ninth International Conference on Cold Fusion*. 2002. Tsinghua University, Beijing, China: Tsinghua University Press. p. 246.

117. Zhang, W.-S. *Characteristics of Excess Heat in Pd D_2O+D_2SO_4 Electrolytic Cells Measured by Seebeck Envelope Calorimetry*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 27-32.
118. Storms, E.K., *Measurements of excess heat from a Pons-Fleischmann-type electrolytic cell using palladium sheet*. Fusion Technol., 1993. **23**: p. 230.
119. McKubre, M.C.H., *et al*. *New hydrogen energy research at SRI*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 75.
120. Liaw, B.Y., *et al*., *Elevated-temperature excess heat production in a Pd + D system*. J. Electroanal. Chem., 1991. **319**: p. 161.
121. Okamoto, H. and S. Nezu, *Measurements of hydrogen loading ratio of Pd anodes polarized in LiH-LiCl-KCl molten salt systems*. Trans. Fusion Technol., 1994. **26**(#4T): p. 59.
122. Yuan, L.J., *et al*. *Neutron monitoring on cold-fusion experiments*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 461.
123. Tsvetkov, S.A., E.S. Filatov, and V.A. Khokhlov. *Excess heat in molten salts of (LiCl-KCl)+(LiD+LiF) at the titanium anode during electrolysis*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 89.
124. Arata, Y. and Y.-C. Zhang, *A new energy caused by "spillover-deuterium"*. Proc. Japan. Acad., 1994. **70 ser. B**: p. 106.
125. Arata, Y. and Y.C. Zhang. *Picnonuclear fusion generated in "lattice-reactor" of metallic deuterium lattice within metal atom-clusters. II Nuclear fusion reacted inside a metal by intense sonoimplantion effect*. in *The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science*. 2002. Tsinghua Univ., Beijing, China: Tsinghua Univ. Press. p. 5.
126. Clarke, B.W., *et al*., *Search for ^{3}He and ^{4}He in Arata-style palladium cathodes II: Evidence for tritium production*. Fusion Sci. & Technol., 2001. **40**: p. 152-167.
127. Case, L., *COPRODUCTION OF ENERGY AND HELIUM FROM D2*. 1997: USA.
128. Iwamura, Y., *et al*. *Detection of anomalous elements, X-ray and excess heat induced by continous diffusion of deuterium through multi-layer cathode (Pd/CaO/Pd)*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 167.
129. Iwamura, Y., T. Itoh, and M. Sakano, *Nuclide transmutation device and nuclide transmutation method*. 2002, Mitsubishi Heavy Industries, Ltd.: U.S.A.
130. Kitamura, A., *et al*. *Search for Nuclear Reaction Products in Gas Phase Experiments – Deuterium Permeation and Absorption –*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 216-220.
131. Yamaguchi, T., *et al*. *Investigation of nuclear transmutation using multilayeredCaO/X/Pd samples under deuterium permeation*. in *ICCF-14 International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC: www.LENR.org. p. 195-202.
132. Yamada, H., *et al*. *Producing transmutation elements on multi-layered Pd samples by deuterium permeation*. in *Condensed Matter Nuclear Science, ICCF-12*. 2005. Yokohama, Japan: World Scientific. p. 196.
133. Murase, A., *et al*., *TOF-SIMS investigation on nuclear transmutation from Sr to Mo with deuterium permeation through multi-layered Pd/CaO*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 34-43.
134. Itoh, T., *et al*. *Observation of nuclear products under vacuum conditions from deuterated palladium with high loading ratio*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 189.
135. Focardi, S., *et al*., *Large excess heat production in Ni-H systems*. Nuovo Cimento, 1998. **111A**(11): p. 1233.
136. Piantelli, F., *Energy generation and generator by means of anharmonic stimulated fusion*. 2010: World Property Organization.
137. Rossi, A., *Journal of Nuclear Physics*. 2012, http://www.journal-of-nuclear-physics.com/.
138. Storms, E.K. and B. Scanlan. *Detection of radiation from LENR*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC: www.LENR.org. p. 261-287.
139. Karabut, A.B. and E.A. karabut. *Research into Spectra of X-ray Emission from Solid Cathode Medium During and After High Current Glow Discharge Operation*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington DC: www.LENR-CANR.org. p. 362-367.
140. Karabut, A.B. and E.A. Karabut. *Electric and Heat Measurements in High Voltage Electrolysis Cell Experiments*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington DC. p. 168-175.
141. Savvatimova, I. *Creation of more light elements in tungsten irradiated by low-energy deuterium ions*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 505-528.
142. Savvatimova, I.B., *Transmutation of Elements in Low-energy Glow Discharge and the Associated Processes*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 181-198.

143. Karabut, A.B. and E.A. Karabut, *Experimental results on Excess Heat Power, Impurity Nuclides and X-ray Production in Experiments with a High-Voltage Electric Discharge System*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 199-216.
144. Karabut, A.B., E.A. Karabut, and P.I. Hagelstein, *Spectral and Temporal Characteristics of X-ray Emission from Metal Electrodes in a High-current Glow Discharge*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 217-240.
145. Dufour, J., *et al*., *Hydrogen triggered exothermic reaction in uranium metal*. Phys. Lett. A, 2000. **270**: p. 254.
146. Dufour, J., *et al*. *Hydrex catallyzed transmutation of uranium and palladium: experimental part*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 153-158.
147. Wipf, H. and V. Erckman, *On permeation techniques for electrotransport studies on metal-hydrogen systems*. Scripta Metal., 1976. **10**: p. 813.
148. Tamaki, M. and K. Tasaka. *Field formation of the condensed matter fusion by electro-transport of deuterium in palladium.* in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 593.
149. Wisniewski, R. and A.J. Rostocki, *Hall effect in the Pd-H system*. Phys. Rev. B, 1971. **3**(2): p. 251.
150. Tsuchida, T., *Role of hydrogen atoms in palladium*. J. Phys. Soc. Japan, 1963. **18**: p. 1016.
151. Bambakidis, G., R.J. Smith, and D.A. Otterson, *Electrical resistivity versus deuterium concentration in palladium*. Phys. Rev., 1969. **177**(3): p. 1044.
152. McKubre, M.C. and F. Tanzella. *Using resistivity to measure H/Pd and D/Pd loading: Method and significance*. in *Condensed Matter Nuclear Science, ICCF-12*. 2005. Yokohama, Japan: World Scientific. p. 392.
153. Coehn, A., Z. Elektrochem., 1929. **35**: p. 676.
154. Botta, E., *et al*. *Measurement of ^4He production from D_2 gas-loaded Pd samples*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 29-35.
155. Celani, F., *et al*., *Deuterium overloading of palladium wires by means of high power microsecond pulsed electrolysis and electromigration: suggestions of a "phase transition" and related excess heat*. Phys. Lett. A, 1996. **214**: p. 1.
156. Del Giudice, E., *et al*. *The Fleischmann-Pons effect in a novel electrolytic configuration*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 47.
157. Granite, E. and J. Jorne, *A novel method for studying electrochemically induced cold fusion using a deuteron-conducting solid electrolyte*. J. Electroanal. Chem., 1991. **317**: p. 285.
158. Mizuno, T., *et al*. *Anomalous heat evolution from $SrCeO_3$-type proton conductors during absorption/desorption in alternate electric field*. in *Fourth International Conference on Cold Fusion*. 1993. Lahaina, Maui: Electric Power Research Institute 3412 Hillview Ave., Palo Alto, CA 94304. p. 14.
159. Mizuno, T., *et al*., *Formation of ^{197}Pt radioisotopes in solid state electrolyte treated by high temperature electrolysis in D_2 gas*. Infinite Energy, 1995. **1**(4): p. 9.
160. Biberian, J.-P. *Excess heat measurements in $AlLaO_3$ doped with deuterium*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 49.
161. McKubre, M.C.H. *Closing comments summerizing the status and progress of experimental studies*. in *The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science*. 2002. Tsinghua Univ., Beijing, China: Tsinghua Univ. Press. p. XVIII.
162. Taleyarkhan, R.P., *et al*., *Recent Advances and Results in Acoustic Inertial Confinement Bubble Nuclear Fusion*, in *Low-Energy Nuclear Reactions Sourcebook Volume 2*, J. Marwan and S. Krivit, Editors. 2009, Oxford University Press.
163. Prevenslik, T.V. *Biological effects of ultasonic cavitation*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 539.
164. Stringham, R. and R. George, *Cavitation induced micro-fusion solid state production of heat, 3He, and 4He*. 1995.
165. Lipson, A.G., *et al*., *Observation of neutrons from cavitation action on substances containing deuterium*. Pis'ma Zh. Teor. Fiz., 1990. **16**(9): p. 89 (in Russian).
166. Arata, Y. and Y.-C. Zhang. *Sono implantation of hydrogen and deuterium from water into metallic fine powders*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 293.
167. Bazhutov, Y.N. and V.P. Koretsky. *Neutron generation at ultrasonic cavitation of some liquids*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 427.
168. Mallove, E., *Excess heat in cavitation devices: World-wide testing reports*. Infinite Energy, 1995. **1**(3): p. 16.
169. Kornilova, A.A., *et al*. *Investigation of Radiation Effects at Bubble Cavitation in Running Liquid*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington DC. p. 418-424.

170. Liu, F.-S., Y. Hou, and W.-F. Chen, *Theory of Fusion During Acoustic Cavitation in C3D6O Liquid*. J. Cond. Matter Nucl. Sci., 2007. **1**: p. 142.
171. Ohta, T., *On the molecular kinetics of acoustic cavitation and the nuclear emission*. Int. J. Hydrogen Energy, 2003. **28**: p. 437.
172. Kim, Y.E., *Cross section for cold deuterium-deuterium fusion*. Fusion Technol., 1990. **17**: p. 507.
173. Kasagi, J. *Screening potential for nuclear reactions in condensed matter*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC: www.LENR.org. p. 318-325.
174. Bush, B.F., *et al*., *Helium production during the electrolysis of D_2O in cold fusion experiments*. J. Electroanal. Chem., 1991. **304**: p. 271-278.
175. Jones, S.E., *Current issues in cold fusion research: heat, helium, tritium, and energetic particles*. Surf. Coatings Technol., 1992. **51**: p. 283.
176. Jones, S.E. and L.D. Hansen, *Examination of claims of Miles et al in Pons-Fleischmann-Type cold fusion experiments*. J. Phys. Chem., 1995. **99**: p. 6966.
177. Camp, W.J., *Helium detrapping and release from metal tritides*. J. Vac. Sci. Technol., 1977. **14**: p. 514-517.
178. Packham, N.J.C., *et al*., *Production of tritium from D_2O electrolysis at a palladium cathode*. J. Electroanal. Chem., 1989. **270**: p. 451.
179. Storms, E. and C.L. Talcott, *Electrolytic tritium production*. Fusion Technol., 1990. **17**: p. 680.
180. Iyengar, P.K. and M. Srinivasan, *BARC studies in cold fusion*. 1989, BARC, India: Bombay.
181. Das, D. and M.K.S. Ray, *Fusion in condensed matter - a likely scenario*. Fusion Technol., 1993. **24**: p. 115.
182. Storms, E.K. and C. Talcott-Storms, *The effect of hydriding on the physical structure of palladium and on the release of contained tritium*. Fusion Technol., 1991. **20**: p. 246.
183. Cedzynska, K. and F.G. Will, *Closed-system analysis of tritium in palladium*. Fusion Technol., 1992. **22**: p. 156-159.
184. Chien, C.-C., *et al*., *On an electrode producing massive quantities of tritium and helium*. J. Electroanal. Chem., 1992. **338**: p. 189-212.
185. Taubes, G., *Cold fusion conundrum at Texas A & M*. Science, 1990. **248**: p. 1299.
186. Anderson, D.M. and J.O.M. Bockris, *Cold fusion at Texas A&M*. Science, 1990. **249**: p. 463.
187. Anderson, J., *et al*., *Letters and response about cold fusion at Texas A&M*. Science, 1990. **249**: p. 463-465.
188. Bockris, J.O.M., *Accountability and academic freedom: The battle concerning research on cold fusion at Texas A&M University*. Accountability in Research, 2000. **8**: p. 103.
189. Claytor, T.N., D.D. Jackson, and D.G. Tuggle, *Tritium production from low voltage deuterium discharge on palladium and other metals*. Infinite Energy, 1996. **2**(7): p. 39.
190. Iyengar, P.K., *et al*., *Bhabha Atomic Research Centre studies on cold fusion*. Fusion Technol., 1990. **18**: p. 32.
191. Notoya, R., *Alkali-hydrogen cold fusion accompanied by tritium production on nickel*. Trans. Fusion Technol., 1994. **26**(#4T): p. 205-208.
192. Takahashi, A., *et al*. *Anomalous excess heat by D_2O/Pd cell under L-H mode electrolysis*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 79.
193. Gozzi, D., *et al*., *Nuclear and thermal effects during electrolytic reduction of deuterium at palladium cathode*. J. Fusion Energy, 1990. **9**(3): p. 241.
194. Jordan, K.C., B.C. Blanke, and W.A. Dudley, *Half-life of tritium*. J. Inorg. Nucl. Chem., 1967. **29**: p. 2129.
195. Corrigan, D.A. and E.W. Schneider, *Tritium separation effects during heavy water electrolysis: implications for reported observations of cold fusion*. J. Electroanal. Chem., 1990. **281**: p. 305.
196. Boucher, G.R., F.E. Collins, and R.L. Matlock, *Separation factors for hydrogen isotopes on palladium*. Fusion Technol., 1993. **24**: p. 200.
197. Yasui, K., *Fractofusion mechanism*. Fusion Technol., 1992. **22**: p. 400.
198. Preparata, G. *Fractofusion revisted*. in *Anomalous Nuclear Effects in Deuterium/Solid Systems, "AIP Conference Proceedings 228"*. 1990. Brigham Young Univ., Provo, UT: American Institute of Physics, New York. p. 840.
199. Carpinteri, A., F. Cardone, and G. Lacidogna, *Piezonuclear Neutrons From Brittle Fracture: Early Results of Mechanical Compression Tests*. Strain, 2009. **45**(4): p. 332-339.
200. Takahashi, A., *et al*., *Emission of 2.45 MeV and higher energy neutrons from D_2O-Pd cell under biased-pulse electrolysis*. J. Nucl. Sci. Technol., 1990. **27**: p. 663.
201. Takahashi, A., *et al*., *Excess heat and nuclear products by D_2O/Pd electrolysis and multibody fusion*. Int. J. Appl. Electromagn. Mater., 1992. **3**: p. 221.
202. Isobe, Y., *et al*., *Search for multibody nuclear reactions in metal deuteride induced with ion beam and electrolysis methods*. Jpn. J. Appl. Phys., 2002. **41**(3): p. 1546-1556.
203. Mosier-Boss, P.A., *et al*., *Comparison of Pd/D co-deposition and DT neutron generated triple tracks observed in CR-39 detectors*. Eur. Phys. J. Appl. Phys., 2010. **51**(2): p. 20901-20911.
204. De Ninno, A., *et al*., *Emission of neutrons as a consequence of titanium-deuterium interaction*. Nuovo Cimento Soc. Ital. Fis. A, 1989. **101**: p. 841.

205. De Ninno, A., *et al*., *Evidence of emission of neutrons from a titanium-deuterium system*. Europhys. Lett., 1989. **9**(3): p. 221.
206. Menlove, H.O., *et al*. *Measurement of neutron emission from cylinders containing titanium with pressurized deuterium gas*. in *Workshop on Cold Fusion Phenomena*. 1989. Santa Fe, NM,. p.
207. Menlove, H.O., *et al*., *Measurement of neutron emission from Ti and Pd in pressurized D_2 gas and D_2O electrolysis cells*. J. Fusion Energy, 1990. **9**(4): p. 495.
208. Kaushik, T.C., *et al*., *Preliminary report on direct measurement of tritium in liquid nitrogen treated TiDx chips*. Indian J. Technol., 1990. **28**: p. 667-673.
209. Keeney, F., *et al*. *Neutron emissions from metal deuterides*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 525.
210. Jones, S.E. *Anomalous neutron emission in metal- deuterium systems*. in *Riken Conference on Muon-Catalyzed and Cold Fusion*. 1989. Tokyo, Japan. p.
211. Akimoto, T., *et al*. *Temperature dependency on counting efficiency of NE213 liquid scintillator for low level neutron measurement*. in *Sixth International Conference on Cold Fusion,Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 295.
212. Bruschi, M., U. Marconi, and A. Zoccoli. *The neutron spectrometer of the cold fusion experiment under the Gran Sasso Laboratory*. in *Hadronic Phys., Winter Course 8th 1993*. 1994: World Sci., Singapore. p. 332.
213. Menlove, H.O. and M.C. Miller, *Neutron-burst detectors for cold-fusion experiments*. Nucl. Instr. Methods Phys. Res. A, 1990. **299**: p. 10.
214. Aoyama, T., *et al*., *Highly reliable low-level neutron detection using 3He proportional counters*. Radioisotopes, 1991. **40**: p. 188.
215. Cisbani, E.M., *et al*., *A neutron detector for CF experiments*. Nucl. Instrum. Methods Phys. Res. A, 2001. **459**: p. 247.
216. Bush, R.T. and R.D. Eagleton. *Experimental studies supporting the transmission resonance model for cold fusion in light water: II. Correlation of X-Ray emission with excess power*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 409.
217. Mizuno, T. and S. S. *Anomalous Heat Generation during Hydrogenation of Carbon (Phenanthrene)*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington DC. p. 147.
218. Lipson, A.G., A.S. Roussetski, and G. Miley. *Evidence for condensed matter enhanced nuclear reactions in metals with a high hydrogen solubility*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 248.
219. Violante, V., *et al*. *Search for nuclear ashes In electrochemical experiments*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 405.
220. Gozzi, D., *et al*., *Erratum to "X-ray, heat excess and ^{4}He in the D/Pd system"*. J. Electroanal. Chem., 1998. **452**: p. 251-271.
221. Karabut, A.B. *X-ray emission in the high-current glow discharge experiments*. in *The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science*. 2002. Tsinghua Univ., Beijing, China: Tsinghua Univ. Press. p. 155.
222. Mosier-Boss, P.A., *et al*., *Review of TwentyYears of LENR Research Using Pd/D Co-deposition*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 173-187.
223. Dong, Z.M., *et al*., *Studies on Anomalous Phenomena of D/Pd Systems using a Gas-loading Process – A Stride Towards Neutrino Detection*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 119-131.
224. Szpak, S., P.A. Mosier-Boss, and F. Gordon, *Further evidence of nuclear reactions in the Pd/D lattice: emission of charged particles*. Naturwiss., 2009. **94**: p. 515.
225. Lipson, A., *et al*. *harged Particle Emissions and Surface Morphology of Pd/PdO:Dx and TiDx Targets Under Electron Beam Excitation*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 187-196.
226. Kowalski, L., *Comments on Codeposition Electrolysis Results*. J. Cond. Matter Nucl. Sci., 2010. **3**: p. 1-3.
227. Srinivasan, M., G. Miley, and E.K. Storms, *Low-energy nuclear reactions: Transmutations*, in *Nuclear Energy Encyclopedia: Science, Technology, and Applications*, S. Krivit, J.H. Lehr, and T.B. Kingery, Editors. 2011, John Wiley & Sons: Hoboken, NJ. p. 503-539.
228. Bockris, J. *History of the discovery of transmutation at Texas A&M University*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, France: World Scientific Co. p. 562.
229. Miley, G.H., *et al*. *Quantitative observations of transmutation products occuring in thin-film coated microspheres during electrolysis*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 629.
230. Miley, G.H., *Possible evidence of anomalous energy effects in H/D-loaded solids-low energy nuclear reactions (LENRS)*. J. New Energy, 1997. **2**(3/4): p. 6.

231. Mizuno, T., *Transmutation reactions in condensed matter*, in *ACS Symposium Series 998, Low-Energy Nuclear Reactions Sourcebook*, J. Marwan and S.B. Krivit, Editors. 2008, American Chemical Society: Washington, DC. p. 271.
232. Bush, R.T. *Evidence for an electrolytically induced shift in the abundance ratio of Sr-88 and Sr-86*. in *International Symposium on Cold Fusion and Advanced Energy Sources*. 1994. Belarusian State University, Minsk, Belarus: Fusion Information Center, Salt Lake City. p. 157.
233. Notoya, R., *Cold fusion arising from hydrogen evolution reaction on active metals in alkali metallic ions' solutions*. Environ. Res. Forum, 1996. **1-2**: p. 127.
234. Ohmori, T., T. Mizuno, and M. Enyo, *Isotopic distributions of heavy metal elements produced during the light water electroysis on gold electrodes*. J. New Energy, 1996. **1**(3): p. 90.
235. Singh, M., *et al*., *Verification of the George Oshawa experiment for anomalous production of iron from carbon arc in water*. Fusion Technol., 1994. **26**: p. 266.
236. Jiang, X.L., L.J. Han, and W. Kang. *Anomalous element production induced by carbon arcing under water*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. p. 172.
237. Ohmori, T. and M. Enyo, *Iron formation in gold and palladium cathodes*. J. New Energy, 1996. **1**(1): p. 15.
238. Ohmori, T., *et al*., *Transmutation in a gold-light water electrolysis system*. Fusion Technol., 1998. **33**: p. 367.
239. Bush, R.T. and R.D. Eagleton, *Evidence for electrolytically induced transmutation and radioactivity correlated with excess heat in electrolytic cells with light water rubidium salt electrolytes*. Trans. Fusion Technol., 1994. **26**(4T): p. 344.
240. Notoya, R. *Nuclear products of cold Fusion caused by electrolysis in alkali metallic ions solutions*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 531.
241. Savvatimova, I. and A. Karabut. *Nuclear reaction products registration on the cathode after glow discharge*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 213.
242. Yamada, H., *et al*., *Producing a radioactive source in a deuterated palladium electrode under direct-current glow discharge*. Fusion Technol., 2001. **39**: p. 253.
243. Dash, J., *et al*. *Effects of glow discharge with hydrogen isotope plasmas on radioactivity of uranium*. in *The Ninth International Conference on Cold Fusion*. 2002. Beijing, China: Tsinghua University. p. 77.
244. Dash, J. and D. Chicea. *Changes In the radioactivity, topography, and surface composition of uranium after hydrogen loading by aqueous electrolysis*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 463.
245. Kervran, C.L., *Transmutations biologiques, metabolismes aberrants de l'asote, le potassium et le magnesium*. Librairie Maloine S. A, Paris, 1963.
246. Vysotskii, V.I., A.A. Kornilova, and I.I. Samoylenko. *Experimental discovery of phenomenon of low-energy nuclear transformation of isotopes (Mn^{55}=Fe^{57}) in growing biological cultures*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 687-693.
247. Komaki, H., *production de proteins par 29 souches de microorganismes et augmentation du potassium en milieu de culture sodique sans potassium*. Revue de Pathologie Comparee, 1967. **67**: p. 213.
248. Komaki, H. *Observations on the biological cold fusion or the biological transformation of elements*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 555-558.
249. Tanzella, F.L., *et al*. *Parameters affecting the loading of hydrogen isotopes into palladium cathodes*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 171.
250. Dardik, I., *et al*. *Report on electrolysis experiments at energetics technologies*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 325.
251. Chicea, D. *Comment on carbon production In deuterium-metal systems*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 475.
252. Chen, S.-K., *et al*., *The microstructure of electrolytically deuterium-loaded palladium rods*. Fusion Technol., 1996. **29**: p. 302.
253. Castagna, E., *et al*. *Metallurgical characterization of Pd electrodes employed in calorimetric experiments under electrochemical deuterium loading*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC: www.LENR.org. p. 444-450.
254. Szpak, S., P.A. Mosier-Boss, and J.J. Smith, *Deuterium uptake during Pd-D codeposition*. J. Electroanal. Chem., 1994. **379**: p. 121.

255. Rout, R.K., *et al*., *Copious low energy emissions from palladium loaded with hydrogen or deuterium*. Indian J. Technol., 1991. **29**: p. 571.
256. Savvatimova, I.B. and A.B. Karabut, *Radioactivity of palladium cathodes after irradiation in a glow discharge*. Poverkhnost (Surface), 1996(1): p. 76 (in Russian).
257. Arata, Y. and Y.C. Zhang, *Helium (^{4}He, ^{3}He) within deuterated Pd-black*. Proc. Jpn. Acad., Ser. B, 1997. **73**: p. 1.
258. Kidwell, D.A., *et al*. *Yes, Virginia there is Heat, but It is Likely of Chemical Origin*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 100-109.
259. Arata, Y., Y.C. Zhang, and X.F. Wang. *Production of Helium and Energy in the "Solid Fusion"*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 72-81.
260. Yamaura, S., *et al*. *Hydrogen absorption of nanoscale Pd particles embedded in ZrO2 matrix prepared from Zr–Pd amorphous alloys*. in *14th International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC: www.LENR.org. p.
261. Takahashi, A., *et al*. *Anomalous Heat Generation in Charging of Pd Powders with High Density Hydrogen Isotopes, (II) Discussions on Experimental Results and Underlying Physics*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 297-302.
262. Iwamura, Y., *et al*., *Detection of anomalous elements, X-ray and excess heat induced by continuous diffusion of deuterium through multi-layer cathode (Pd/CaO/Pd)*. Infinite Energy, 1998. **4**(20): p. 56.
263. Liu, B., *et al*. *"Excess heat" in a gas-loaded D/Pd system with pumping inside palladium tube*. in *8th International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*. 2007. Catania, Sicily, Italy: The International Society for Condensed Matter Science. p. 204.
264. Biberian, J.-P. and N. Armanet. *Excess heat production during diffusion of deuterium through palladium tubes*. in *8th International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*. 2007. Catania, Sicily, Italy: The International Society for Condensed Matter Science. p. 19.
265. Kozima, H. and S. Watanabe. *Nuclear processes in trapped neutron catalyzed model for cold fusion*. in *5th International Conference on Cold Fusion*. 1995. Monte-Carlo, Monaco: IMRA Europe, Sophia Antipolis Cedex, France. p. 347.
266. Fisher, J.C., *Polyneutrons as agents for cold nuclear reactions*. Fusion Technol., 1992. **22**: p. 511.
267. Widom, A. and L. Larsen, *Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces*. Eur. Phys. J., 2006. **C46**: p. 107.
268. Daddi, L., *Proton-electron reactions as precursors of anomalous nuclear events*. Fusion Technol., 2001. **39**: p. 249.
269. Chatterjee, L., *Electrolysis in thin-film nickel coatings: mimicking supernova physics?* Fusion Technol., 1998. **34**: p. 147.
270. Mills, R.L. and W.R. Good, *Fractional quantum energy levels of hydrogen*. Fusion Technol., 1995. **28**: p. 1697.
271. Dufour, J., *et al*. *The Hydrex concept-effect on heavy nuclei*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 431.
272. Dufour, J.J., J.H. Foos, and X.J.C. Dufour, *Formation and properties of hydrex and deutex*. Infinite Energy, 1998. **4**(20): p. 53.
273. Liu, F.S., *The phonon mechanism of the cold fusion*. Mod. Phys. Lett. B, 1996. **10**: p. 1129.
274. Hagelstein, P.L. *Phonon-exchange models: Some new results*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, France: World Scientific Co. p. 743.
275. Violante, V. and A. De Ninno. *Quantum mechanical description of a lattice ion trap*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 221.
276. Kalman, P. and T. Keszthelyi, *Attractive d–d interaction via phonon exchange in deuterated Pd*. Nucl. Instr. and Meth. in Phys. Res. B, 2005. **240**: p. 781-789.
277. Kucherov, Y. *Slow nuclear excitation model*. in *Sixth International Conference on Cold Fusion, Progress in New Hydrogen Energy*. 1996. Lake Toya, Hokkaido, Japan: New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan. p. 502.
278. Chubb, S.R. and T.A. Chubb. *Theoretical framework for anomalous heat and ^{4}He in transition metal systems*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 385.
279. Bazhutov, Y.N. *Erzion discovery in cosmic rays and its possible great role in nature in framework of Erzion model of cold nuclear transmutation*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 269.
280. Matsumoto, T., *'Nattoh' model for cold fusion*. Fusion Technol., 1989. **16**: p. 532.
281. McKibben, J.L., *Evidence for three primordially created particles and can one of them catalyze cold fusion?* 1989.

282. Rafelski, J., *et al*., *Nuclear reactions catalyzed by a massive negatively charged particle. How Cold Fusion Can Be Catalyzed*. Fusion Technol., 1990. **18**: p. 136.
283. Preparata, G. *Theoretical ideas on cold fusion*. in *The First Annual Conference on Cold Fusion*. 1990. University of Utah Research Park, Salt Lake City, Utah: National Cold Fusion Institute. p. 91.
284. Capek, V., *Tunnelling efficiency and the problem of cold fusion*. Czech. J. Phys., 1989. **B39**: p. 793.
285. Hora, H., G. Miley, and J. Kelly, *Low-energy nuclear reactions of protons in host metals at picometer distance*. Trans. Am. Nucl. Soc., 2000. **83**: p. 357.
286. Hora, H., *et al*., *Proton-metal reactions in thin films with Boltzmann distribution similar to nuclear astrophysics*. Fusion Technol., 1999. **36**: p. 331.
287. Hora, H., *et al*. *Shrinking of hydrogen atoms in host metals by dielectric effects and Inglis-Teller depression of ionization potentials*. in *The 9th International Conference on Cold Fusion, Condensed Matter Nuclear Science*. 2002. Tsinghua Univ., Beijing, China: Tsinghua Univ. Press. p. 135.
288. Miley, G.H., H. Hora, and Y. X. *Condensed Matter "Cluster" Reactions in LENRs*. in *ICCF-14 International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC.: http://lenr-canr.org/acrobat/MileyGHcondensedm.pdf. p. 451-457.
289. Miley, G.H. *Emerging physics for a breakthrough thin-film electrolytic power unit*. in *Space Technol. Applic. Int. Forum*. 1999. p. 1227.
290. Miley, G., *et al*. *Cluster reactions in low energy nuclear reactions (LENR)*. in *8th International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*. 2007. Catania, Sicily, Italy: The International Society for Condensed Matter Science. p. 235-251.
291. Miley, G., X. Yang, and H. Hora, *Ultra-High Density Deuteron-cluster Electrode for Low-energy Nuclear Reactions*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 256-268.
292. Badiei, S., P.U. Andersson, and L. Holmlid, *Laser-induced variable pulse-power TOF-MS and neutral time-of-flight studies of ultradense deuterium*. Phys. Scr., 2010. **81**(4).
293. Isobe, Y., *et al*. *Search for coherent deuteron fusion by beam and electrolysis experiments*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 17-22.
294. Takahashi, A. *Tetrahedral and octahedral resonance fusion under transient condensation of deuterons at lattice focal points*. in *ICCF9, Ninth International Conference on Cold Fusion*. 2002. Beijing, China: Tsinghua University: Tsinghua Univ., China. p. 343.
295. Hagelstein, P.I., *On the connection between Kα X-rays and energetic alpha particles in Fleischmann–Pons experiments*. J. Cond. Matter Nucl. Sci., 2010. **3**: p. 50-58.
296. Kim, H.Y. *Bose-Einstein Condensation Nuclear Fusion: Theoretical Predictions and Experimental Tests*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 288-296.
297. Kim, Y.E., *Bose–Einstein Condensate Theory of Deuteron Fusion in Metal*. J. Cond. Matter Nucl. Sci., 2011. **4**: p. 188-201.
298. Cornell, E.A. and C.E. Wieman, *The Bose-Einstein Condensate*. Sci. Am., 1998. **278**(3): p. 40-45.
299. Zwierlein, M.W., *et al*., *Observation of Bose–Einstein Condensation of Molecules*. Phys. Rev. Lett., 2003. **91**: p. 250401.
300. Campari, E.G., *et al*. *Nuclear reactions in Ni-H systems*. in *6th International Workship on Anomalies in Hydrogen/Deuterium Loaded Metals*. 2005. Siena, Italy. p.
301. Campari, E.G., *et al*. *Surface analysis of hydrogen-loaded nickel alloys*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, France: World Scientific Co. p. 414.
302. Campari, E.G., *et al*. *Photon and particle emission, heat production and surface transformation in Ni-H system*. in *11th International Conference on Cold Fusion*. 2004. Marseilles, France: World Scientific Co. p. 405.
303. Campari, E.G., *et al*. *Overview of H-Ni systems: Old experiments and new setup*. in *5th Asti Workshop on Anomalies in Hydrogen / Deuterium loaded Metals*. 2004. Asti, Italy. p.
304. Battaglia, A., *et al*., *Neutron emission in Ni-H systems*. Nuovo Cimento, 1999. **112 A**: p. 921.
305. Focardi, S., *et al*. *On the Ni-H system*. in *Asti Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*. 1997. Villa Riccardi, Italy: Societa Italiana Di Fisica. p. 35.
306. Badiei, S., P.U. Andersson, and L. Holmlid, *Fusion reactions in high-density hydrogen: A fast route to small-scale fusion?* International J. Hydrogen Energy, 2009. **34**(1): p. 487.
307. Badiei, S., P.U. Andersson, and L. Holmlid, *Production of ultradense deuterium: A compact future fusion fuel*. Appl. Phys. Lett., 2010. **96**: p. 124103.
308. Arachi, Y., *et al*., *Structural analysis of nano-sized-Pd/ZrO2 composite after H(D) absorption*. Solid State Ionics, 2006. **177**: p. 1861.
309. Takahashi, A., *et al*. *Deuterium Gas Charging Experiments with Pd Powders for Excess Heat Evolution (II). Discussions on Experimental Results and Underlying Physics*. in *The 9th Meeting of Japan CF-Research Society*. 2009. Shizuoka, Japan: www.lenr.org. p.

310. Celani, F., *et al. High temperature deuterium absorption in palladium nano-particles*. in *International Conference on Condensed Matter Nuclear Science , ICCF-13*. 2007. Sochi, Russia: Tsiolkovsky Moscow Technical University. p. 181.
311. Mansoori, G.A., P.L. Barros de Araujo, and E. Silvano de Araujo, *Diamondoid molecules*. 2012: World Scientific, Impertial College Press.
312. Dmitriyeva, O., *et al. Deuterium & hydrogen loading into nano-Pd on zeoliteand alumina matrices at low pressures*. in *ICCF-16*. 2011. Chenni, India. p.
313. Frisone, F., *Theoretical model of the probability of fusion between deuterons within deformed crystalline lattices with microcracks at room temperature*. Fusion Sci. & Technol., 2001. **40**: p. 139.
314. McIntyre, R. *Proposal for an experiment designed to seek evidence for cold fusion*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: World Scientific Publishing Co. p. 611.
315. Mills, R., *The grand unified theory of classical quantum mechanics*. 2006, Ephrata, PA: Cadmus Professional Communications. 1450.
316. Frisone, F. *Probability of deuteron plasmon fusion at room temperature within microcracks of crystalline lattices with deuterium loading*. in *8th International Conference on Cold Fusion*. 2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy. p. 443.
317. Bockris, J.O.M. and P.K. Subramanyan, *The equivalent pressure of molecular hydrogen in cavities within metals in terms of the overpotential developed during the evolution of hydrogen*. Electrochim. Acta, 1971. **16**: p. 2169.
318. Vigier, J.P. *New hydrogen energies in specially structured dense media: capillary chemistry and capillary fusion*. in *Third International Conference on Cold Fusion, "Frontiers of Cold Fusion"*. 1992. Nagoya Japan: Universal Academy Press, Inc., Tokyo, Japan. p. 325.
319. Sinha, K.P. and A. Meulenberg, *Lochon-mediated low-energy nuclear reactions*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 55-63.
320. Kim, Y.E. and T.E. Ward, *Bose–Einstein condensation nuclear fusion: Role of monopole transition*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 101-107.
321. Schwinger, J., *Cold fusion: a hypothesis*. Z. Naturforsch., 1990. **45A**: p. 756.
322. Storms, E.K., *A study of those properties of palladium that influence excess energy production by the Pons-Fleischmann effect*. Infinite Energy, 1996. **2**(8): p. 50.
323. Bockris, J.O.M., D. Hodko, and Z. Minevski, *Fugacity of hydrogen isotopes in metals: degradation, cracking and cold fusion*. Proc. Electrochem. Soc, 1992. **1992**: p. 92.
324. Kopecek, R. and J. Dash, *Excess heat and unexpected elements from electrolysis of heavy water with titanium cathodes*. J. New Energy, 1996. **1**(3): p. 46.
325. Klopfenstein, M.F. and J. Dash. *Thermal imaging during electrolysis of heavy water with a Ti cathode*. in *The Seventh International Conference on Cold Fusion*. 1998. Vancouver, Canada: Eneco Inc. p. 98.
326. Dash, J. and Q. Wang. *Anomalous Silver on the Cathode Surface after Aqueous Electrolysis*. in *15th International Conference on Condensed Matter Nuclear Science*. 2009. Rome, Italy: ENEA, Italy. p. 38-41.
327. Bashkirov, Y.A., *et al*., *Observation of neutron emission from electrolysis of heavy water*. Pis'ma Zh. Tekh. Fiz., 1990. **16**(19): p. 51 (in Russian).
328. Lipson, A.G., *et al*., *Reproducible neutron emission by the combined effect of cavitation and electrolysis at the surface of a titanium cathode in electrolyte based on heavy water*. Pis'ma Zh. Teor. Fiz., 1991. **17**(21): p. 33 (in Russian).
329. Izumida, T., *et al*., *A search for neutron emission from cold nuclear fusion in a titanium-deuterium system*. Fusion Technol., 1990. **18**: p. 641.
330. Jianyu, H., *et al. Experimental study on anomalous neutron production in deuterium/solid system*. in *Anomalous Nuclear Effects in Deuterium/Solid Systems, "AIP Conference Proceedings 228"*. 1990. Brigham Young Univ., Provo, UT: American Institute of Physics, New York. p. 193.
331. Bruschi, L., *et al*., *Search for neutron emission from a deuterium-titanium system*". Europhys. Lett., 1989. **10**(4): p. 303.
332. Patterson, J.A., *Method for electrolysis of water to form metal hydride*. 1994: US Patent # 5,318,675.
333. Celani, F., *et al*., *Development of a high temperature hybrid CMNS reactor*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 24-33.
334. Stringham, R., *When bubble cavitation becomes sonofusion*. J. Cond. Matter Nucl. Sci., 2012. **6**: p. 1-12.
335. Szpak, S., P.A. Mosier-Boss, and J.J. Smith, *On the behavior of Pd deposited in the presence of evolving deuterium*. J. Electroanal. Chem., 1991. **302**: p. 255.
336. Karabut, A. *Research into powerful solid X-ray laser (wave length is 0.8-1.2 nm) with excitation of high current glow discharge ions*. in *11th International Conf. on Emerging Nuclear Energy Syst*. 2002. Albuquerque, NM. p. 374.
337. Khajavikhan, M. and Y. Fainman, *Thresholdless Nanoscale Coaxial Lasers*. Nature, 2012.
338. Iwamura, Y., M. Sakano, and T. Itoh, *Elemental analysis of Pd complexes: effects of D_2 gas permeation*. Jpn. J. Appl. Phys. A, 2002. **41**(7): p. 4642-4650.