A Comprehensive Understanding of Cold Fusion

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ABSTRACT

The fusion of the isotopes of hydrogen has now been demonstrated to occur in a wide variety of materials after special treatments. This source of energy has the potential to meet the need for clean energy that is not affected by political conflicts and excessive cost. In addition, the mechanism reveals a new kind of nuclear interaction. The cold fusion mechanism is here explained based on observed behavior with testable predictions. An effective guide is now available to create a useful energy generator using only water as the source of the hydrogen fuel. The model results in a new value of 4.01841 for the mass of ^{4}H, which is proposed to decay with a short half-life to ^{4}He by beta emission after being emitted from the fusion reaction.

I. INTRODUCTION

Thirty-six years ago, two professors at the University of Utah, Martin Fleischmann and Stanley Pons[1, 2] discovered that deuterium could be made to fuse in palladium metal to produce helium and heat energy as the final products. This discovery was initially rejected for reasons explained in several books.[3-6]

Nevertheless, the proposed nuclear process was immediately recognized as being a potential source of clean, cheap, and easily available energy that could be obtained from the hydrogen nucleus in ordinary water.[7] The application would enable civilization to reach a higher level while the problems caused by oil extraction and burning would be eliminated. A paper is available at www.LENR.org that explores the serious political implications of its application[8] and suggests one of the reasons why it was rejected by some governments.

Now, after 36 years of study by laboratories in many countries, proof for the claim of fusion in a chemical system has been achieved. This evidence is based on a comparison between many measured values for the He/energy ratio[9] and the ratio calculated using the well-known equation $E=Mc^2$, where M is the mass change when two D fuse to produce ^{4}He, as plotted in Fig. 1. Most of the missing helium that prevents an exact match to this value has been found trapped in the PdD structure. Such agreement between three kinds of independent measurements (helium, energy, and mass change) is very unlikely to result from chance or error. Note also, the agreement remains when fusion is caused either by electrolysis or by direct reaction with D_2 gas. Other features of this relationship are discussed in Section III.

In addition, hundreds of studies have produced tritium, a radioactive isotope of hydrogen that is not present in the environment at such levels. Neutrons were also detected that have a correlation to the amount of tritium, as shown in Fig. 2.[10] Other nuclear reactions were found to produce elements not initially present along with neutrons, as explained in Section III. These behaviors are only possible as the result of nuclear reactions.

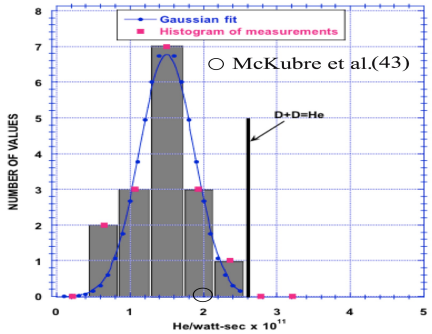

FIGURE 1. Histogram of measured He/energy values compared to the ratio obtained using the mass change when the fusion reaction D+D=He occurs in PdD using electrolysis.[11] The vertical line represents 23.85 MeV/He. The value attributed to McKubre et al.[12] resulted from a study of coconut charcoal+5% Pd heated in D_2 gas.

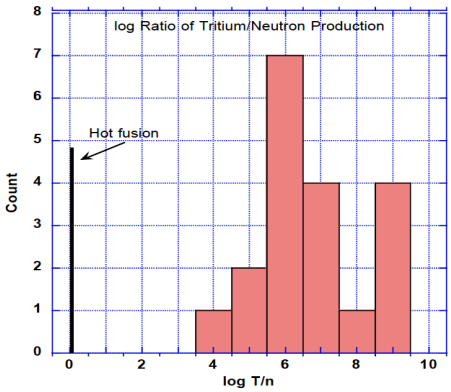

FIGURE 2. Relationship between the number of reported values and the log of the measured tritium/neutron ratio produced by cold fusion resulting from the use of various treatments. The ratio resulting from the hot fusion mechanism is well-established at a value near unity or log T/n = 0. (Storms[10])

Ordinary hydrogen was thought not to fuse, providing a blank to demonstrate the imagined errors in the heat measurements. This false conclusion resulted because the early calorimeters were unable to detect the resulting small amount of heat. Later studies have demonstrated that hydrogen (p) fuses as easily as the deuteron, while producing nearly as much energy when the combined fusion events are considered. (Section III.5)

This behavior along with thousands of examples of energy too great to result from a chemical source proves that the claims for fusion were correct and the rejection was not warranted. When this large collection of observed behavior is considered, the mechanism causing fusion can be understood as a logical process, as described here.

However, a source of confusion has resulted in two conflicting treatments and explanations being applied. One in one case, kinetic energy is applied to D+, which is used to bombard a material containing D. When the energetic D+ nuclei and the dissolved D atom collide, fusion occurs. The nearby electrons in the crystal structure cause the fusion event to become more probable than expected as the amount of applied kinetic energy is decreased. The fusion reaction produces fragments of ^{4}He, which include tritium, as shown in Table 1. The first two fragments occur with nearly equal

probability regardless of applied energy. The emission of a gamma ray, required to balance momentum, is rarely detected. All materials containing D produce this fusion process regardless of previous treatment when they are exposed to D+ having kinetic energy. These studies have been underway for over 25 years.[15-19] The resulting nuclear process has been proposed by some people to describe the cold fusion process[20], with the failure to detect the emitted neutrons being explained by their absorption in the surrounding material. Because the nuclear products are identical to those produced when the reaction occurs in plasma, this process is identified by the term "hot fusion" when discussed here.

TABLE 1

Nuclear products resulting when kinetic energy is applied to deuterium either in plasma or in a chemical structure. Czerski[13, 14].

$$^{2}H + {}^{2}H \rightarrow \begin{cases} {}^{3}H + p & E_p \sim 3.6\ MeV \quad E_t \sim 1.2\ MeV \\ {}^{3}He + n & E_n \sim 2.4\ MeV \quad E_\tau \sim 0.8\ MeV \\ {}^{4}He + \gamma & E_\gamma \sim 24\ MeV \end{cases}$$

In contrast, D is found to fuse to produce intact ^{4}He gas atoms when no kinetic energy is applied, as shown in Fig. 1. This process is identified as "cold fusion". Only certain materials are found to cause the nuclear process when treated in special ways. In addition, the fusion reactions are found to occur only at special isolated locations within the material.

Because these two different mechanisms involve electrons in different ways, they need to be discussed as separate subjects. Only the "cold fusion" mechanism is discussed here.

The main problem is the need to understand the true nature of the nuclear process so that the reaction could be made reproducible and the rate increased to industrial levels. Toward this end, many explanations have been proposed[21] based mainly on the imagination with very little support from the observed behavior. Some of these ideas have been evaluated by Storms[22].

This paper explains the process at both the operational and scientific levels, based on the author's observations and those published by others. The operational level describes HOW the process can be carried out. The scientific level explains WHY such a reaction is possible. Both explanations are based solely on observed behaviors and the established rules of chemical and nuclear behavior, without the need for a complex mathematical description. This approach provides an easy-to-understand path for an effective study and can suggest important features needed to design an energy generator.

II. OPERATIONAL EXPLANATION

The many studies reveal that the nuclear process does not occur informally throughout the material[23] Instead, it occurs only at a few locations, which are called the nuclear-active-environment (NAE). When these unique locations are absent, the nuclear reaction will not occur. Therefore, the number of these sites in the material will determine the fusion rate. The nature of these sites is explained in Section III.1.

All sources of practical energy have three features in common. First, a source of fuel is easily available. Second, the fuel has a means to move from its stored location to the site where energy is generated. Finally, the energy generation process takes place at a

special location designed for this purpose. In the case of cold fusion, the fuel is the isotopes of hydrogen, which are located in the chemical structure, and moves to the site where fusion occurs by normal diffusion. This process can be described by the equation in Table 2 containing the variables observed to influence the rate at which energy is generated by cold fusion.

TABLE 2

Equation describing the controlling variables.

$$\text{Power (watt)} = N * \exp(-E/(RT)) * I^2 * H * f(T,p)*C * dC/dx$$

Each of the variables has an influence on the rate of energy production by the cold fusion process, but generally by an unknown amount. Each variable is discussed below.

N: This number represents the number of sites where the fuel is converted to energy, called here the Nuclear Active Environment (NAE). The amount of power produced by each NAE is determined by the value of the other variables. The distribution of the NAE in a material is also important because a local region will melt if the local concentration is too high. Examples of the melting behavior are summarized by Nagel and Moser[24]. Pons and Fleischmann[25] observed self-heating when suitable conditions were created throughout a material. The nature of this environment is discussed in Section III.1.

T: Temperature (K) is an important variable that influences the diffusion rate, hence the rate at which two fuel nuclei can find and enter the NAE. The equation that describes the influence of temperature on diffusion is shown. An example of its effect on the amount of power is plotted in Fig. 3 where the measured values are plotted as temperature vs power and as log power vs 1/T. The linear behavior in the second plot demonstrates that the power follows the same behavior as does diffusion[26], thus supporting the claimed relationship. In addition, the ability of H(p) to produce fusion energy is demonstrated to have the same behavior as does the D+D fusion reaction, as shown in Fig. 4.

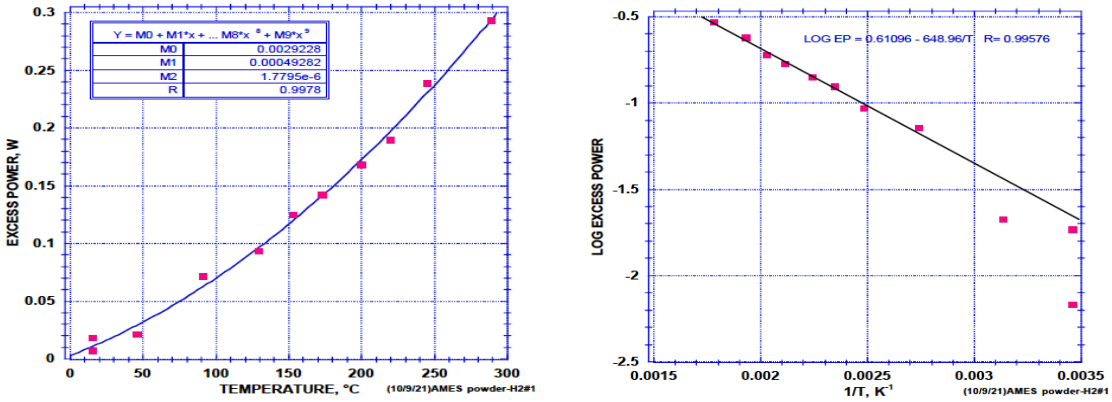

FIGURE 3. Powdered ZrO_2+(Pd-Ni-Zr-O) alloy heated in H_2 gas. The sample was first heated over the temperature range and then cooled. The calorimeter was allowed to reach steady state for 110 min between each temperature change. This method of activation has been used in Japan by Takahashi et al.[27] The sample was provided by NASA.

Notice that so little power occurs at low temperature, this material would have been considered inactive if the early insensitive calorimeters were used or if the sample

had not been studied at higher temperatures. This behavior is very common and accounts for the poor early success.

E: In addition to temperature, the diffusion rate is determined by the activation energy needed to cause the nuclei to move from their stable locations. The activation energy is measured as the slope of the resulting straight line when log power is plotted vs 1/T. Figure 4 compares the behavior of several samples containing different values for the D/Pd ratio. All of the samples have the same slope, which means that they all have the same activation energy regardless of the D/Pd ratio. The value is close to the activation energy for diffusion of D in PdD.[26] Other materials show different activation energies.

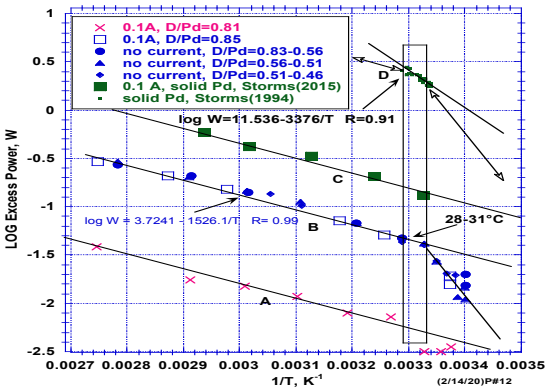

FIGURE 4. Relationship between log (excess power) vs 1/T for solid samples heated in an electrolytic cell. The studies labeled A, B, C, and D were made at different times using different samples of PdD, each having about the same weight.

C: McKubre et al.[28] measured the excess power as a function of D/Pd ratio at constant temperature. The resulting behavior shown in Fig. 5 can be explained if a change in activation energy occurred as the D/Pd ratio increased above 0.85. Using the average behavior, the change in activation energy is plotted in Fig. 6. This change causes an increase in the rate of diffusion, which increases the ability of the D to interact with the NAE. The activation energy is independent of the D/Pd ratio at lower concentrations and, therefore, has no effect on the fusion rate. This conclusion is demonstrated in Fig. 7 where the amount of power is not changed when the D/Pd ratio is changed. Similar behaviors are shown in Fig. 4. The complete absence of D stops energy production as expected.

The frequent effort to achieve a high D/Pd ratio is futile because the required pressure (chemical activity) of the gas is very difficult to achieve and maintain. Increased temperature combined with a convenient fuel content is a better condition.

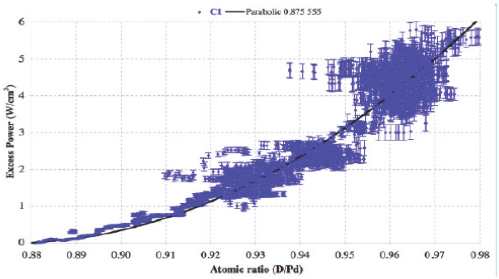

FIGURE 5. Effect of D/Pd ratio on the measured power at 20° C reported by McKubre et al.[28] when the electrolytic method is used. The behavior is obtained using a single batch of Pd metal that contained some NAE.

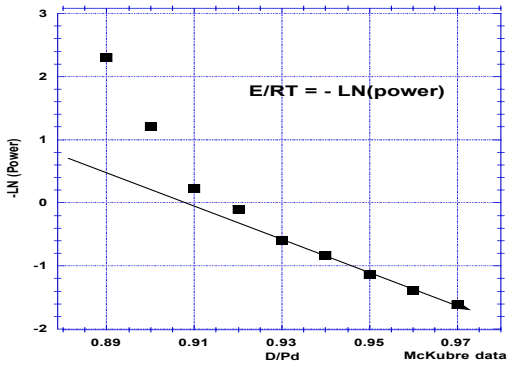

FIGURE 6. Plot of ln power vs D/Pd that shows the behavior of the activation energy as the D/Pd ratio is increased based on the values plotted in Fig. 5.

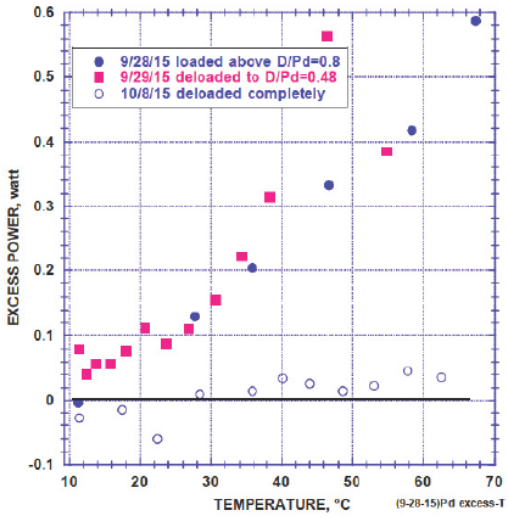

FIGURE 7. A Pd plate weighing about 2 g heated in an electrolytic cell containing D_2O + LiOD. The D/Pd ratio is measured using the orphaned oxygen method.[29]

H: The number is related to the D/(D+H) ratio with the smallest value being produced when 100% H is present and the largest value when 100 % D is present in the material.

The influence of this variable is determined by the energy released by the respective fusion process, as described in a later section.

dC/dx: A concentration gradient has been found to cause the fusion rate to increase[30]. The motion of ions through the gradient would increase the chance encounter between the fuel and the NAE.

I – A current that is passed through a conductor will cause the atoms to move in response to the charge gradient and the electron flow.[31] This process, called electromigration, increases the probability of a fuel nuclei encountering a NAE. The increased power does not result from the D ions concentrating at the negative electrode because this accumulation takes time while the effect of applied current on energy production is instantaneous. An example of this behavior is shown in Fig. 8. A magnetic field[32] is expected to increase the effect of this variable.

When electrolysis or gas discharge is used, this current is applied automatically. Indeed, the effect of applied current on the power produced by electrolysis might be caused by this process combined with a small increase in temperature, examples of which are shown in Fig. 9.

R - gas constant

p – effective gas pressure of H_2 or D_2. This pressure determines the fuel/metal ratio in the material.

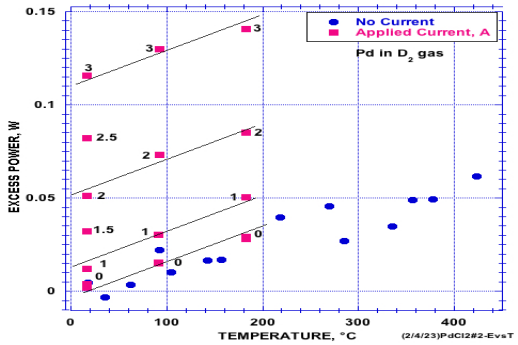

FIGURE 8. Effect of applied current is shown in units of ampere(A). The values for "no current" were obtained first followed by the values designated as "applied current". The current at a constant temperature was measured and then the temperature was increased and held for 100 min until the temperature became constant.[11]

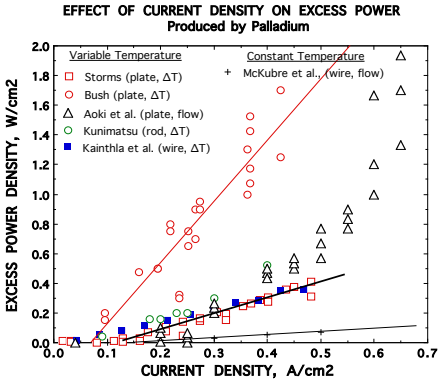

FIGURE 9. Effect of electrolytic current on excess power.[10]

III. SCIENTIFIC EXPLANATION

The formation of ^{4}He from deuterium (Fig. 1) reveals two serious problems. The first involves a mechanism to reduce the Coulomb barrier between the two D without destroying the local chemical environment. This possible consequence is important because the chemical bonds involve only a few eV of energy, which is far less than would be needed to cause fusion, regardless of the proposed mechanism. In addition, the Second Law of Thermodynamics prohibits the spontaneous concentration of energy except at a small random level. A resonance process does not eliminate these limitations.[33-36]

The second problem involves a method to dissipate the resulting energy while conserving momentum. The latter problem results because the fusion reaction has no mass to spare so as to match the momentum of the emitted single nuclear product. The proposed gamma ray (Table 1) is not emitted.

In addition, the cold fusion mechanism is not related to the hot fusion mechanism that results when kinetic energy is applied because the two conditions produce different nuclear products at different locations in a material.

III.1: Nature of the NAE

The first problem to solve involves the reduction in the Coulomb barrier. The conventional fusion process (hot fusion) applies kinetic to the nuclei to achieve this result. Because such energy cannot occur spontaneously in a chemical system, a different mechanism is required.

This mechanism is proposed to involve a high concentration of negative charge that can form locally in a material under certain conditions. This concentrated charge is proposed to reduce the positive charge on the hydrogen nuclei, thereby along closer approach. How the required condition might be achieved is described next.

The normal electrons in a chemical system are not able to achieve the reduction because they have a special relationship to each other. This special relationship is identified as a crystal structure where the absence of any atom would produce a vacancy. The electrons that create this structure are not available to have any other relationship without Gibbs energy being supplied, which is not available. Therefore, the electrons in the vacancies cannot initiate fusion because these electrons would not be available to reduce the Coulomb barrier between D nuclei in the vacancy. In addition, the claim for the presence of metal atoms vacancies in the material in which fusion is proposed to occur is based on an incorrect interpretation of the behavior.[22]

Therefore, a different condition is required. I propose that when the crystal relationship is locally destroyed, the electrons normally associated with the metal atom are no longer able to have a stable relationship to each other. An example of such a damaged site is shown in Fig. 10. Therefore, a few unbonded electrons are available to interact with nearby D nuclei in new ways. These new ways are proposed to cause the positive charge on the D nuclei to be reduced by the now available negative charge, thereby allowing the nuclei to get close enough for their strong force to interact.

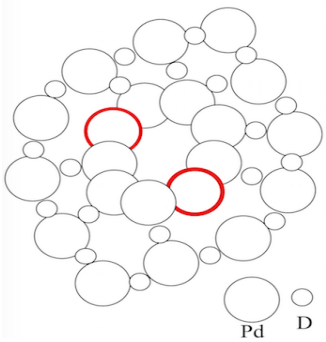

FIGURE 10. The gap is a three dimensional structure surrounded by metal atoms in a chaotic arrangement with the D atoms being largely absent in the wall. The metal atoms shown in the cartoon with a heavy wall have electrons available to cause fusion of hydrogen nuclei in the gap.

The size of this distorted region is important because it needs to be small enough for the negative charge density resulting from the nearby-distorted electrons to be large enough to reduce the positive charge on the D nuclei but larger than a normal atom vacancy. The required size is proposed to be in the 10 nm range.

These distorted sites have been created in different materials using different treatments, as listed in Table 3. These treatments cause a random number of sites to form, which results in unpredictable amount of power. The challenge is to discover how the sites can be made in large number with total control. Nanomachining or controlled deposit of atoms to produce gaps with the critical size are suggested as a useful methods.

TABLE 3

Examples of successful treatments to produce nuclear active material

Researcher	Material	Treatment	Result
Fleischmann+Pons[2]	Pd	Long electrolysis in D_2O +LiOD	Deposit of Li, many flaws
Takahashi et al.[27]	Zr+Pd+Ni	Oxidation	Powder ZrO_2+metals
Storms[37]	Pd + CaO particles	melting	Small particles of CaO imbedded in Pd metal
Storms[26]	Pressed powders	Pressing, heating, rolling	Small sites between particles
Zhao et al. [38]	Small particles of Pd	Sintering	Porous structure
Dardik et al.[39]	Pd	Superwave	Many flaws
Mizuno et al. [40]	Ni mesh	Sanding+Pd deposit	Many flaws
Iwamura et al. [41]	Pd on CaO	React with D_2	Stress cracks
Case[42]	Coconut charcoal+Pd	Heat with D_2	Many impurities
Biberian et al. [43]	hydrotalcite	Heating in H_2	Nanoparticles of Ni

The mechanism by which the Coulomb barrier is reduced by local electrons is new and is not described here in mathematical detail. Nevertheless, the presence of a strong negative charge in the environment is proposed to reduce the positive charge on the D+ nuclei enough to allow the strong force to interact. These electron could now interact with the resulting combined nuclear energy states, thereby having access to the released energy.

The studies by Czerski et al.[18] and others demonstrate that the local electrons can help in the reduction process when a small amount of energy is supplied from outside the system. Nevertheless, this process does not produce an intact helium nucleus, as does cold fusion, even at the lowest applied energy, which means the process should not be called cold fusion.[14]. Clearly, the mechanism changes when no energy is applied and the process takes place in the NAE. How and why this happens requires further study.

III.2: Emission of ^{4}H

Because all of the nucleons supplied by the deuterium fuel are present in the resulting ^{4}He nucleus, it cannot be emitted with kinetic energy because nothing is available to balance the momentum when 23.84 MeV is released (Fig. 1).

Although people have seen various emissions, a clear identification has been only provided by Karabut et al.[44](KK) (Fig. 11), who thought they were detecting ^{4}He, which is impossible. Storms and Scanlan[45](SS) (Fig. 12), using the same methods, saw the same emissions that they identified as an isotope of hydrogen, not ^{4}He. The observed ^{4}He gas is proposed to result from the beta decay of ^{4}H. Perhaps the pits in CR-39 attributed to alpha emission might also have been produced by this energetic ^{4}H emission.[46] Because alpha energy was used for calibration, the resulting calculated energy of the assumed ^{4}He would be incorrect.[47]

Of significant importance, the emissions show a series of energies each of which differs from the next by approximately the mass energy of the electron (0.511 MeV), as plotted in Fig. 13. This type of emission is unique to cold fusion and needs to be explained. This is done in Section III.5.

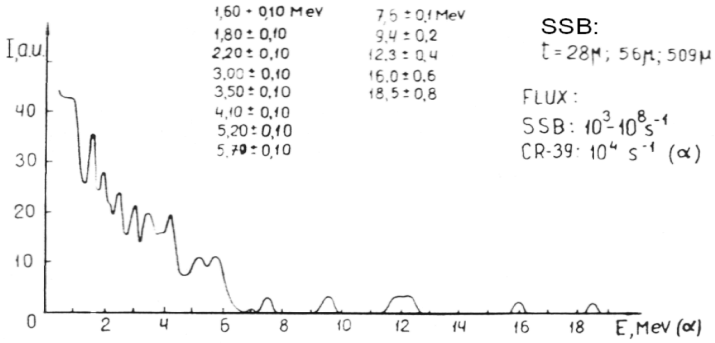

FIGURE 11. Energy measured using a silicon barrier detector for ions emitted from Pd by gas discharge in D_2.[44] KK

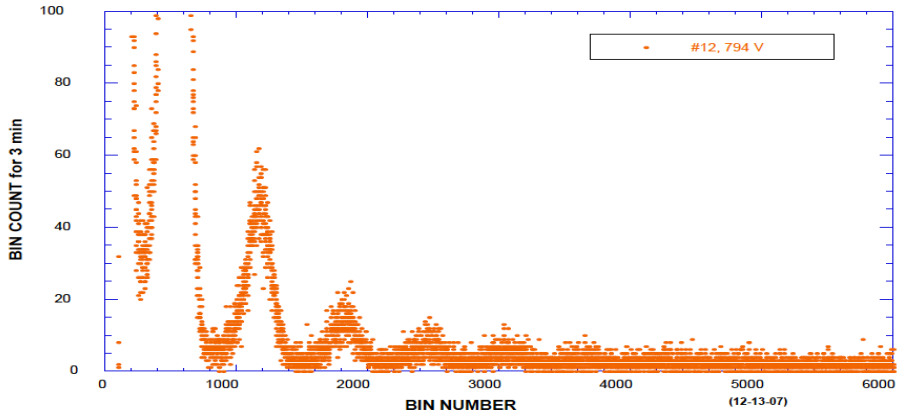

FIGURE 12**.** Energy measured using a silicon barrier detector for ions emitted from Pd by gas discharge in D_2 + H_2.[45] SS

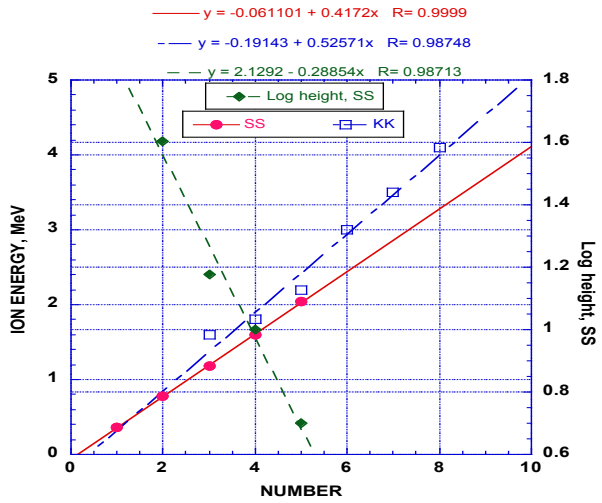

FIGURE 13. Comparison between the data sets in Figures 11 and 12. The log ion intensity is obtained from the data in Fig. 12. The first value in Fig. 11 is assumed to be point #3 in the sequence with the previous values being hidden in the noise.

III.3: Sequence of Events

The process is best understood first as a series of events, each of which can then be evaluated using observed behavior, as is done next.

1. A flaw is formed within the physical structure in which some electrons associated with the formation of the crystal structure are released from their committed roles. As a result, they are now free to enter into other relationships while their negative charge is made available to interact with the local environment in new ways. This flaw is called the Nuclear Active Environment (NAE).
2. A hydrogen nucleus enters the flaw by diffusion from its normal location in the surrounding crystal structure, via well-known mechanisms that apply to all materials. Once inside, the positively charged nucleus is captured by the strong negative charge in the environment. Subsequently, a second hydrogen nucleus enters the NAE through the same diffusion process. Increasing the diffusion rate

thus increases the rate of local accumulation and the number of fusion reactions/sec.

3. The large negative charge in the NAE reduces the positive charge on each hydrogen nucleus. This reduction lets the two nuclei approach close enough for their nuclear components to interact via the strong force. This process is more complex than the proposed electron screening process.[.[48, 49]
4. The electrons that lower the Coulomb barrier are proposed to participate directly in the fusion process. They do this by altering the energy states of the nuclei via their interactions with the strong force. This means the electrons are integrated into a new kind of energy structure with nucleons, and both share in the released mass-energy. The structure is expected to have quantized energy levels, limiting the number of electrons that can participate.
5. This growing structure becomes increasingly unstable until the structure explodes, ejecting electrons in all directions. Momentum is conserved as the nuclear energy is released as kinetic energy. One electron stays in the nuclear product because this reduces the amount of energy emitted as kinetic energy that must be matched by the momentum, thus reducing the number of emitted electrons. The amount of energy carried by the nuclear product is determined by how many electrons have joined the assembly before its decomposition. Each missing electron adds the same amount of energy to the kinetic energy of the nuclear product, thereby producing a series of equally spaced energies.
6. Each isotope of hydrogen will experience the same mechanism but will produce a different amount of energy and emitted electrons. The details of each fusion process are discussed in the next section.
7. The kinetic energy is converted to heat as the nuclear product moves through the structure. **Bremsstrahlung** radiation is released as the electrons move through the material. Some electrons escape and are detected as an emitted current. This is shown in Figs. 14, 15, and 16. The nature of these electrons is described in Section III.7.
8. The ^{4}H rapidly decays to form stable ^{4}He, and the ^{3}H (tritium) slowly decays to form stable ^{3}He. The deuterium does not decay because it is stable. Some of the ^{4}He and electrons are trapped in the material and are not detected
9. Some of the emitted ^{4}H has enough kinetic energy to cause an additional nuclear reaction when it encounters a nearby nucleus. This process is called transmutation[50] and results in the emission of the occasionally detected neutrons and creation of new elements some of which are radioactive.

III.4 Details of the fusion process

Table 4 summarizes the behavior of deuterium and hydrogen. The description is based on a single universal mechanism that applies to all isotopes of hydrogen. Notice that the mechanism converts one hydrogen isotope to another, two of which eventually decay to an isotope of helium.

Any nucleus of helium that remains in the NAE can be transmuted by the reaction with the emitted energetic ^{4}H to form isotopes of lithium. Likewise, the Pd in the environment can be transmuted to isotopes of silver.[50, 51] Consequently, when

operating over a long time, this mechanism has the ability to create most of the natural elements.

TABLE 4

Summary of the nuclear products and total energy
resulting from fusion of the hydrogen isotopes.
Antineutrino emission is expected when beta decay occurs.

$D+e+D = {}^{4}H$ + electrons + 9.63 MeV
${}^{4}H = {}^{4}He$ + e + 14.21 MeV (23.84 MeV total)

$H+e+H = {}^{2}H$ + electrons + 0.93 MeV
$H+e+{}^{2}H = {}^{3}H$ + electrons + 5.47 MeV
$H+e+{}^{3}H = {}^{4}H$ + electrons + 5.09 MeV
${}^{4}H = {}^{4}He$ + e + 14.21 MeV (19.30 MeV total)

${}^{3}H+e+{}^{2}H = {}^{4}H$ + neutron+ electrons + 3.37 MeV
${}^{4}H = {}^{4}He$ + e + 14.21 MeV (23.98 MeV total)

Deuterium:

To calculate the energy from the D+e+D fusion reaction, the mass of ${}^{4}H$ must be known. Because the mass given in the literature is estimated from the assumed decay by neutron emission,[52, 53] this value is not suitable. The mass used here is based on the behavior of the transmutation reaction described by Storms[50], which is 4.01841 amu. The energy released when ${}^{4}H$ forms is calculated from the mass change according to the following equation.

$$ {}^{2}H + e + {}^{2}H = {}^{4}H + 9.634 \text{ MeV} $$

When ${}^{4}He$ forms, the total energy of 23.85 MeV is achieved when the ${}^{4}H$ decays by beta emission. This decay releases 14.21 MeV, with some energy carried by an antineutrino, which the calorimeter cannot detect and is therefore missing from the energy values in Fig. 1.

This generated energy does not appear as kinetic energy of the emitted ${}^{4}H$ because most is carried by emitted electrons (Section III.6). Instead, the ${}^{4}H$'s kinetic energy shows a series of values (Fig. 13), averaging 0.471 MeV. This average is a lower limit because some energy is lost as the ${}^{4}H$ passes through the solid.

Resolving this apparent contradiction requires combining four observations. First, SS and KK show this emission occurs at equally spaced energies (Figs. 11, 12, 13). Second, SS demonstrates the emission is an isotope of hydrogen, not helium. Third, each fusion event emits many electrons (Storms, Fig. 14). Finally, emitted electrons have an energy range far above chemical sources, as shown by work function or thermionic emission (Figs. 15, 16).

The behavior suggests the assembly of nucleons and electrons "explodes" after it has acquired a certain number of electrons, with this number being variable. The energy not carried by the missing electrons must be carried by the ${}^{4}H$. If twenty electrons were the maximum number of electrons that the assembly can hold, each electrons would carry about 0.48 MeV as kinetic energy. If by chance, additional electrons were missing from

the assembly when the "explosion" occurs, this missing energy also would have to be carried by the ^{4}H as an additional 0.48 MeV. Thus, a series of equally spaced energies would be produced by an increasing number of missing electrons with decreasing probability. The emitted electrons would acquire a velocity to achieve the required energy, with each of the electrons being emitted in a direction that exactly balances the momentum of the other electrons and the emitted ^{4}H.

Hydrogen:

According to Table 4, fusion of H (p) with another H will produce a deuteron with the release of 0.93 MeV. If another H were to enter the NAE before the assembly "exploded", it would immediately fuse to make tritium, which would add 5.47 MeV. Again, if the energetic assembly remained in the NAE, it would fuse with the next H that arrives and add 5.09 MeV to the total energy generated by the process. Consequently, when the resulting complex "explodes", it would release 11.49 MeV by emitting ^{4}H and electrons. The ^{4}H would decay to form ^{4}He. If the active structure exploded before the next H arrived, less energy would result and some T or D would be detected in the material.

In summary, the fusion of four H in three events could produce 23.98 MeV with a sufficient number of electrons emitted to dissipate the energy and conserve the momentum, and with ^{4}He being the final nuclear product. Also, the amount of power would be determined by the rate at which the series of H is able to enter the same NAE. Therefore, the amount of energy released by the fusion of H can be highly variable.

When the fusion of hydrogen occurred, a series of equally spaced energies, similar to the behavior of D, would be predicted for each fusion product. The amount of energy separation would reveal important information about the nature of the process.

III.5 The Nature of the Electron Emission

The emitted electrons have been detected[11, 54-57] and first studied by Gordon et al.[58-61] Storms measured the energy of the emitted electrons (Fig. 14) by applying a voltage between the emitter and collector such that the voltage would prevent any electron having an energy less than the voltage to be returned to the emitter and not measured as a current. The result (Fig. 15) shows that the energy has a range of values that exceeds 100 eV. This amount of energy is too large to result from the effect of the work function as proposed by Gordon et al.[61]

The applied retarding potential results in a current that decreases with time at low applied voltages and increases after a greater amount of retarding voltage is applied, as shown in Fig. 16. The increased retarding voltage also increases the amount of excess power being measured, as shown in Fig. 15. Perhaps, the current being returned to the emitter stimulates the fusion process. This unusual behavior needs to be studied in more detail.

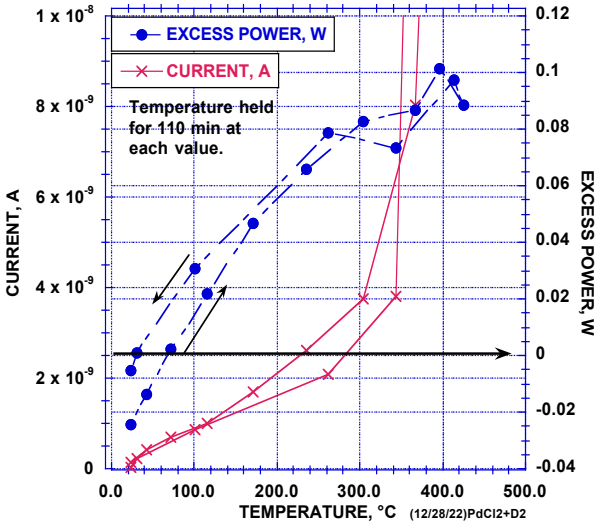

FIGURE 14. Comparison between excess power and electron emission current from and activated sample of α-PdD + β-PdD in D_2 as a function of temperature. Comparison between the excess power and the electron current indicates that about 30 electrons are emitted by each fusion reaction between deuterons.

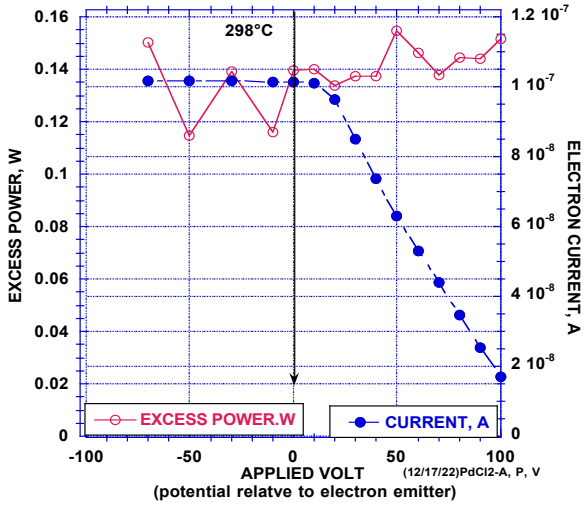

FIGURE 15. Effect of a voltage applied between the emitter and collector on the electron current at 298° C, based on the behavior plotted in Fig 14. The excess power is also shown. The voltage polarity is such that electrons with less than the plotted voltage are caused to return to the electrode surface, hence are not measured as an emitted current.

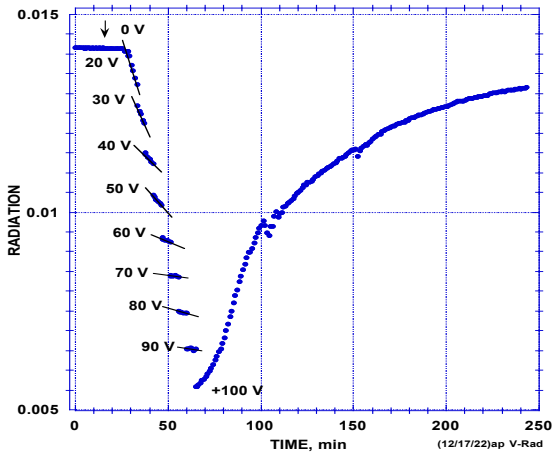

FIGURE 16. Effect of time on the measured current shown in Fig. 15, plotted as arbitrary units identified as Radiation. The voltages applied between the emitter and the collector for each measurement are identified.

IV. Summary

The claim for the fusion of hydrogen nuclei by Profs. Fleischmann and Pons has been demonstrated. The initial rejection was neither justified based on the evidence nor consistent with how scientists are expected to respond to new ideas.

The fusion reaction between deuterons produces ^{4}H with electrons being emitted to carry most of the energy and conserve the resulting momentum, The detected helium results from the rapid beta decay of ^{4}H. The process is consistent with a mass of 4.01841 amu for the unstable ^{4}H nucleus.

Fusion of light hydrogen is more complex with a series of fusion events at the same nuclear active site. Fusion of four H by a series of fusion reactions results in ^{4}H and a neutron, with the ^{4}H producing ^{4}He by beta decay. If the intermediate nuclear products dissipate their energy before they can be reacted with another H, the resulting fusion products will accumulate in the inactive material and surrounding gas. This process is proposed to result in the observed tritium gas.

Both fusion reactions emit electrons that carry most of the nuclear energy and conserve the momentum. These electrons can be collected as an emitted current and used as a source of electrical energy, as suggested by Gordon and Whitehouse.

Some fusion products have sufficient kinetic energy to overcome the Coulomb barrier and produce transmutation products, which results in other elements, some of which are radioactive. Neutron emission conserves the momentum.

Once the underlying mechanism is correctly understood, fusion reactions are expected to provide an exceptionally clean, economically viable, and convenient source of energy. The transmutation reactions are expected to result in the synthesis of novel isotopes and elements not commonly available.

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