
THE COMPLEX CONDITIONS NEEDED TO OBTAIN NUCLEAR HEAT FROM D-Pd SYSTEMS

J. O'M. Bockris ¹

ABSTRACT

The D/Pd system does not show nuclear effects until after several hundred hours of electrolysis although cathodes become saturated with D in 1% of this time. Even then, only a small fraction (10-20%) of electrodes manifest nuclear reactions. More than one-half of the anomalous heat arises from nuclear reactions involving the metal atoms, with gain or loss of protons. The gap in time between the saturation of the substrate and the switch on of anomalous heat is taken up by the gradual spread throughout the electrode material of a state of damage. The damage gives rise to an increase in an internal dislocation concentration. On the dislocated areas, adsorbed protons lose their charge and are susceptible to incorporation into the substrate nuclei.

The irreproducibility arises from the effect of adsorbed impurities from the solution. These influence the desorption mechanism for H or D evolution which in turn cause changes in the internal fugacity of H₂ or D₂ and thus affects the spreading of internal damage, and cracking. Traditional concepts of cracking refer to extreme cracking when a massive number of connected cracks reach the surface and decrease the internal fugacity of deuterium. Internal factors affecting reproducibility arise because the technique making the Pd (or etc.) varies the grain size and this affects the spread of the dislocation-loaded areas.

Anodes of Pt dissolve and the Pt contaminates the surface of the electrode. Doped TiO₂, NiO₂ and LaNiO₃ are good anodes. D₂ and H₂ anodes eliminate anode dissolution. Insufficiently investigated are alloying and its effects on mechanical properties and the spread of damage.

INTRODUCTION

When Fleischmann and Pons [5] reported their discovery of anomalous heat production in D-Pd cathodes, they did not mention two characteristics of such systems.

- (1) Using small cylindrical electrodes, it is necessary (usually) to electrolyze for more than 300 hours before anomalous effects are seen.
- (2) Even then, only about 1/5 of the electrodes show the anomalous behavior within 600 hours.

This (rather than prejudice) is the heart of the difficulty in acceptance of the phenomenon. It is so difficult to find the conditions which give anomalous results.² Nevertheless, some of the experiments will repay the patient experimenter with a display of astounding and entirely anomalous nuclear phenomena (X rays, heat, tritium,

¹ Department of Chemistry, Texas A&M University, College Station, TX 77843-3255

² In the original announcement on TV, it was stated by Fleischmann that – contrary to appearances – it was a difficult experiment. In retrospect, this seems to have been understood in British idiom. Translated into American it reads: "Terribly difficult, needing enormous patience, time, and much skill."

helium, other new nuclei) as has been shown by several hundred scientists in dozens of countries (in more than 1000 publications) over the last seven years.

This paper provides some insight into ways in which this frustrating situation may be interpreted, - and perhaps improved.

THE FACTS OF THE IRREPRODUCIBILITY

The gross facts have already been stated above. The likelihood of success depends little on the pretreatment of the electrode (cold working, polished surface, Pd black, etc.) [1] Three pieces of Pd from the same rod may be "dead" (i.e., behave classically) while the fourth produces tritium [1], or helium [2] and heat, etc. The purity of the solution has a counter-intuitive effect, i.e., solutions specially purified are less likely to be the source of "on" displays than solutions made from ordinary distilled water. Some additives (e.g., thiourea) increase the likelihood of observing anomalous heat. [25]

There are several ways of increasing the likelihood of producing heat, and two of them are related.

1. **Saw-toothed cycling.** One cathodically polarizes, gradually making the potential more negative over (e.g.) one hour and then reducing the overpotential to zero and beginning to rise towards the negative again. Repeating the saw tooth for several days tends to produce anomalous heat more quickly than does steady state polarization. [3]
2. **Cathodic-anodic pulsing.** There is evidence [4] that pulsing the electrode from the potential for hydrogen evolution to that of oxygen many times is effective in stimulating nuclear activity. However, the period in timing and potential amplitude have not been studied.³

Is a Post-Saturation Effect a Vital in Obtaining Significant Heat?

1. The switch-on time.

Since 1989, it has been assumed that a D + D reaction is the origin of the nuclear phenomena which are alleged to give heat.⁴

Thus, the reaction



³ Apart from the basic difficulty that the US government funds cold fusion work only in its own laboratories (no external funding), another matter is that few of the researchers engaged are physical electrochemists. One finds, e.g., that an experienced researcher with several publications reporting low temperature nuclear phenomena, will ask: "What is overpotential?" However, the log-rate of tritium production has been found to be linear with the overpotential [2]. Lack of observation of the individual electrode potential controlling the rate of the tritium production exponentially is one cause of the large variation in rate reported.

Unfortunately, this absence of researchers who understand potential measurement and control of individual electrodes, who know Luggin capillaries and reference electrodes, - applies particularly to the well-funded Japanese group in the Institute devoted to low temperature nuclear reactions in Sapporo.

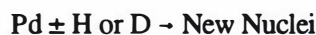
⁴ Most persons aware of what is misleadingly called "Cold Fusion" believe that the studies were begun by Fleischmann and Pons. It seems likely, that this was the honest opinion of these workers. However, low temperature nuclear phenomena were reported in modern times by Borghi. [6] French work was led by Kervran [7] and Japanese work by Kushi. [8] Most remarkable is that an intense study of the production of neutrons by passing a strong current through wires was carried out in US Government labs in the 1970's/ [9] It seems strange that this was not brought out in the violent rejection of Fleischmann et al's early work.

has been cited as a **possible** mechanism. [10] However, measurements of He^4 from electrodes under high overpotential [10] gave only about 1/3 - 1/2 the He^4 in the gas phase necessary to serve as basis for the observed heat in the Pd-D system, i.e., somewhat more than one-half the heat arises in some other way.

There have been a number of reports in the last few years which describe proton capture reactions, i.e., nuclear reactions in solids containing dissolved H isotopes in which not only isotopes of Pd but also new nuclear species are detected from reactions in the cold. There is evidence for fission and fusion. The reaction rate is small but unmistakable, in some cases being measurable by γ -ray spectroscopy. In experiments other than those in the original D-Pd system as much as 56% of stable (non-radioactive) new nuclei have been found present.

According to Kucherov et al. [11], new nuclei (other than H^3 and He^4) found as a result of plasma formation between Pd electrodes in a D_2 atmosphere may contribute significantly to the anomalous heat arising in such systems. The formation of many new nuclei in solid systems, some containing H or D, was reported by Karabut et al. [11]. Similar findings have been reported more recently by Bush [12], Mizuno [13], Ohmori and Enyo [14], Dash [15] and others.

On this basis, it seems reasonable to hypothesize that in D-Pd cells, in general, reactions of the kind:



can occur and that the formation of such nuclei forms a component of the heat observed in the Fleischmann-Pons phenomena. Circumstances necessary for the function of these reactions must be taken into account in any consideration of the several hundred hours of electrolysis which may be necessary to bring about a **switch on** of nuclear activity in D-Pd cells.

Thus, the time to reach saturation with D after the **switch on** of electrolysis will be dependent on the electrode's shape. Detailed solutions to Fick's Second Law for objects of varying shapes are given in Moelwyn-Hughes [16]. However, the time it takes for a diffusion front to reach a distance R (the radius of cylindrical electrode) can be roughly computed from von Schmolokowski's simple equation.

$$R^2 = 2D\tau \quad \text{where } D \text{ is the diffusion rate and } \tau \text{ is elapsed time.}$$

Then, with $D = 10^{-6} \text{ cm}^2 \text{ sec}^{-1}$ and $\Delta = 1.5 \text{ mm}$, $\tau = 5 \cdot 10^4 \text{ sec} = 3 \text{ hours}$. But this is much less than the many hundreds of hours reported as the **switch on** time for the commencement of nuclear activity. The value of D used above is for the initial diffusion into the metal. As the D/Pd ratio increases, D falls [17]. However, it would have to fall to less than $10^{-8} \text{ cm}^2 \text{ sec}^{-1}$ with increasing D concentration to give the correct order of magnitude for the **switch on** time and this decrease seems unlikely. Indeed, there is evidence that the heat producing activity occurs in the surface layer, e.g., 1μ deep, and the H diffusion front would reach such distances in around a millisecond after switch on. The **switch on** of nuclear activity needs hundreds of hours and hence some additional factor apart from $D/Pd = 1$. We know that this factor depends intimately on the crystal structure of the Pd; and on the surface concentration of impurities, for this factor affects the surface activity of the adsorbed D intermediate in D_2 evolution which in turn (together with the overpotential) controls the fugacity, [18] of the dissolved D, and that of D_2 in internal voids (in which pressures $> 10^4$ atmospheres can be reached).

Is the factor, to start proton capture reactions of the type described above, the attainment of highly concentrated dislocation areas within the Pd? Is the formation of such areas rate-determined by the gradual spread of damage. (See Fig. 1)

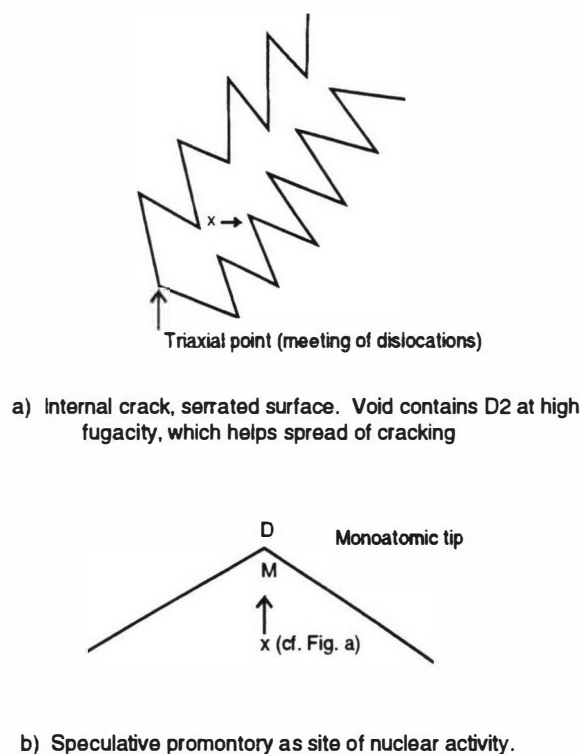


FIG. 1. Possible sites of internal damage at which nuclear activity may be initiated.

hours after initiating an experiment. Workers who talk about "cracking" mean sufficient cracking to give channels to the interface (i.e., D₂ escape).

Bockris and Flitt [20] published photographs of the sporadic movement of cracks under mechanical stress in Fe saturated with H. Such cracks develop large numbers of dislocations. Bockris and Subramaniam [21] calculated an increase of H activity at dislocations (as a function of overpotential) and found that it reached several orders of magnitude over the D_{Ad} activity on planar surfaces [22]. Do the dislocations arising from the spreading of cracks (Fig. 1), which cause super high surface activity of adsorbed deuterons which is the factor leading to proton capture (D⁺ with Pd)? Is the key to the observation of anomalous heat and new nuclei the spread of D (or H) damage up to but **not** including the condition for escape from the surface?

Such a hypothesis would lead to some interpretation of the irregular and unpredictable functioning of the phenomena would come within the horizon of explanation. Uncontrolled surface impurities from the solution would determine, adventitiously, the mechanisms of D₂ evolution, hence the magnitude of the internal D₂ fugacity, and in turn, the degree type of cracking. High overpotential would increase the internal D fugacity though the extent of this factor would depend on the mechanism of hydrogen evolution) but the extent of adsorbed H atoms likely to undergo proton capture is schematically displayed in Fig. 1, would depend on the degree of internal broken areas and voids. The spread of internal damage with time would lead to switch on and the bursts of activity characteristic of the phenomena (including the sporadic spreading of cracks: then stopping, then moving on, etc., observed by Flitt, Revie and Bockris [20]. Each new burst in the crack spreading would give greater heat than the last as more internal surfaces were created, a phenomenon clearly observed by Hodko and Bockris [22].

Thus, to obtain nuclear phenomena would need several conjoint happenings: one of these is the right degree and type of impurities in solution to give adsorbed surface material which in turn influences the mechanism of

It may be that the need for impurities in the solution (adsorbed, therefore, on the electrode), is to affect the mechanism of the hydrogen evolution reaction so as to give high internal D₂ fugacity in voids in the metal. Thus, it seems reasonable to suppose that the right degree of internal cracking is the prerequisite for nuclear activity. The need for this to occur to a sufficient extent may be the factor which delays for so long the onset of nuclear activity. Cracking is usually regarded by workers in this field as a factor inimical to the switch on of nuclear phenomena. Indeed, cracks which reach the surface leak D₂ out of the system and reduce the fugacity of D in the metal.

Before the work of Minevski [39], it was not realized that internal damage begins inside Pd electrodes at quite low overpotentials ($\eta \sim 0.2$ v) and hence is always present within a few

hydrogen or deuterium desorption and thus, the internal fugacity and tendency to crack.⁵ Another is sufficiently high overpotential to create a sufficiently high internal fugacity for the deuterium evolution mechanism to be operative.

But why do some pieces of Pd work, others not, - from the same rod? Is it possible that relatively small changes in grain size can affect the internal spread of cracks? Could such local changes in internal structure arise from thermal irregularities in solidification or cold working in rod manufacture? Or is the function of certain Pd specimens always due to the surface impurity content which could vary with each solution?

K. Shoulders [40] has recently suggested a model for the occurrence of nuclear reactions within solids in the cold and his model also depends, as the present one, on damage. It would thus also be consistent with the several hundred hours delay before **switch on**. The rest of Shoulders model involves a concept of "clusters" of electrons which would undergo acceleration under local electric fields. The energy of these accelerated electrons, would be the origin of the nuclear reaction.

Importance of the Substrate Thickness and Mechanical Properties

Although one critical factor for the attainment of nuclear activity has been put forward as intermediate degree of internal damage, other factors are important.

Thus, the thickness of the electrode (controlling the time to saturation) is important. It might be thought that the thinnest continuous surface film of Pd on some non-interactive substrate (e.g., Ni) might be optimal. However, according to the experiments performed by Minevski [19], the formation of new nuclei does not begin in Pd until a depth of $\sim 1\mu$ [23]. Hence, a thickness **greater than 1μ** but as thin as is practical with this condition (say, 10μ) may be the most appropriate thickness.

The ductility of the electrodeposits is easily controlled by means of a variation of the overpotential and by the nature of concentration of additives [24]. Because of the importance of the right degree of cracking, the ductility of Pd becomes of importance and this may also be varied by means of electrochemical techniques [24] (control of overpotential, pulsing regimes, superimposed a.c., etc.).

Codeposition of D₂ with Pd.

The reversible deposition potential for



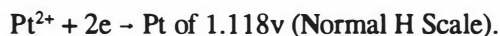
is +0.951 on the normal H scale; and that of H₂ at pH 14, E° -0.812. Hence, at any overpotential (and also with acid solution) Pd will be co-deposited with D₂ evolution.

This co-deposition increases the advantage of the electrochemical method for the formation of a successful system. This effect was first evidenced by Szpak and Boss [25] (cf. also Hodko and Bockris [26]), who codeposited Pd and D₂ onto Au substrates and found that it greatly reduced **switch on time** (~ 50 hrs) for the production of nuclear residues compared with those for a solid cylindrical electrode (~ 500 hrs).

⁵ In an erudite and detailed discussion of the factors which have to be conjointly present if one is to obtain a **switch on** of nuclear activity, Storms [38] dismisses cracking as wholly negative. But he means "cracks which reach the surface and release D₂ into the ambience." Storms concentrates on D + D reactions and neglects the Pd + D \rightarrow new nuclei aspects.

Importance of a Non-dissolving Anode

The adsorption of impurities on the cathode is helpful if the impurity (as tends to be the case) increases the deuterium overpotential for a given cathodic reaction rate [27]. The walls of the cell and the dissolution of the anode are important sources of impurities (SiO₂, Pt). A platinum anode (frequently used by many workers in this field) has a reversible potential for



At pH = 14 the reversible potential for O₂ evolution is + 0.42 (Normal H Scale). At a current density of 1 amp cm⁻², the oxygen over potential on Pt at 25 °C can be roughly estimated by the approximate equation [28]:

$$\eta = 2RT/F \ln i/i_0$$

where R is the molar gas constant in J per mol per °K, T is temperature in °K, F is the Faraday, or charge on 1 mol of ions in Coulombs.

If i_0 is taken at 10⁻¹⁰ amps cm⁻² and $\eta = 1$ atmosphere cm⁻²; $\eta = 1.12$. Hence, the Pt dissolution would occur under an overpotential of (1.52 - 1.12) = + 0.40 v. Were there to be no other reaction occurring on the Pt surface, the dissolution rate would be (with $i_0 = 10^{-6}$ amp cm⁻²).

$$i = 10^{-6} \times 10^4 = 10^{-2} \text{ amps cm}^2$$

However, the **partial** rate will be much less than this because of the competing O₂ evolution. If this reduction is given by the ratio of the calculated Pt dissolution to that of O₂ evolution at 1 amp cm⁻² (both for 1 sq cm of occupancy), the effective rate is ~ 10⁻⁴/10² = 10⁻². A rate of 10⁻² amps cm⁻² on a bare surface without competition would become an effective rate per sq cm of 10⁻²/10² = 10⁻⁴ amps cm⁻².

These very rough estimates⁶ suggest that Pt could have a concentration in a 100 cc cell after 100 hrs as high as 3 10⁻³ moles per liter and a limiting current for the deposition of Pt of around ($i_L = 0.025$ nc) 100μ amp cm⁻². Because of the codeposition of D₂ the effective current density will be less than this perhaps) 1/10⁻⁴ ~ 10⁴ less, i.e., about 10⁻² amps Cm⁻². After 100 hrs, up to 100 monolayers of Pt could be on the Pd cathode. Such predictions have been confirmed by the direct measurements of Minevski [29].

Such deposition acts to **catalyze** D₂ evolution and **decrease** the internal fugacity of D₂, and hence diminish the probability of a nuclear switch on. Thus, **Pt anodes should not be used in cells in which it is hoped to manifest nuclear activity.**

Among possibilities [30] for non dissolving anodes would be Pd itself, but also, (doped) TiO₂, NiO₂, CoO₂, La_xNiO₃ [31]. Valuable work in this direction has been done by Tseung and by Conway and Liu. [32] It is of value to have large ("black") deposits on the anode to decrease the current density and hence the anode potential. Various geometric arrangement of cells to increase the area are possible [33].

⁶ There will be further cause for reduction of the current density below that calculated because of the formation of thin oxide films likely to impede Pt dissolution by ~ 10² times.

Importance of Alloying; Other Cathode Materials

Pd easily forms alloys with other metals, e.g., Pd-Ni alloys (particularly with 25-85% by weight Pd). There are two purposes in alloying. One is to influence and control the surface reaction. But the most important, – in view of the central position given in this paper to internal cracking, – is to control the ductility of the alloy compared with Pd.

It has been suggested that the ability of a structure to set off nuclear effects is related somewhat parabolically to the degree of cracking and time of electrolysis (Fig. 1). Although this **right degree of internal damage** is a prime key to the interpretation of irreproducibility, long time delays in starting, and bursts in heat output (Fig. 1 and Fig. 2), it is accepted that **too much cracking is harmful**.⁷

Alloying of Pd with Ni [34] may be a way to control this. Pd-Ni alloys are less sensitive to H-induced cracking than Pd. Conversely, they are more susceptible than is Pd to stress cracking. These properties are perhaps the reason for the success of the (Clean Energy Technology, Inc.) cells, which used Pd alloys. The mechanical properties of the electrode, how it depends on the concentration of D, and the switch on of heat evolution, demand research.

Investigation of other metals and their ability to promote nuclear burning of H and D will be important. According to Kim [35] proton capture by heavy metals may be more likely than with light ones.

Other H absorbers such as Ti, Ta, Nb, V provide attractive possibilities. The relation of the nuclear side to structure needs study. What of Th, U, Np as cathodes?

SUMMARY

The hypothesis suggested here is that the **right degree of internal cracking and structural damage** inside Pd is a necessary prerequisite to the manifestation of nuclear effects. If cracking is too much, the cracks reach the surface and D₂ escapes. **Internal cracks** increase the internal dislocation concentration per cc. At dislocations, adsorbed D activity is known to be greatly increased [37]. Proton capture (metal + H or D → new nuclei) is postulated to be a maximum at pointed and serrated edge sites within the damaged surfaces. The quirkiness of the phenomena is due to the fact that the following have to occur together: a sufficiently high internal D₂ fugacity and an optimal degree of internal damage (Fig. 1). Cracks develop and spread in bursts [20], which correspond to those of the

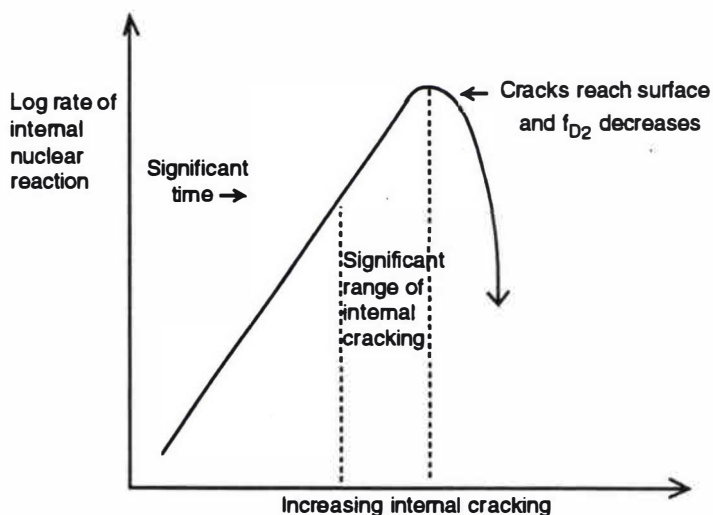


FIG. 2. Schematic of the nuclear reaction rate assumed to depend on the degree of internal cracking. What is often referred to perjoratively as "cracking" is the condition whereby the cracks reach the surface and D₂ escapes from the system, reducing D and, hence, the likelihood of nuclear reaction velocity.

⁷ Most workers in this field do not understand that internal damage and cracking in Pd begins at overpotentials of -0.3v. When they refer to "cracking," they mean "cracking which reaches the surface and reduces f_{D2}."

heat evolution. The long wait in the experiments is for sufficient cracks to form. The touchy dependence on grain size built in during manufacture of the samples serves to interpret "live" and "dead" pieces of Pd.

Impurities in solutions may increase D surface coverage and hence internal D_2 fugacity (hence cracks). Overpotential must be high, though if too high, cracks will reach the surface and decrease of internal fugacity.

The optimal electrode thickness is around 10 microns. Cylinders and thicker plates will be poor performers. Electrodeposition, under a superimposed ac regime, and codeposition of Pd and D_2 will reduce $\tau_{\text{switch on}}$.

Pt as an anode will reduce the probability of observing phenomena because it converts the Pd surface [29] to a Pt one and catalyzes D_2 evolution, reducing internal fugacity and hence the presence of adsorbed D at internal dislocations where its surface activity is maximal. Pd itself, or oxide anodes, e.g., doped TiO_2 , $La_x NiO_3$ or anodic D_2 dissolution from Pd may be optimal [37] for the anodic O_2 evolution.

Alloy electrodes provide a means of controlling the optimal amount of internal cracking. Pd-Ni is a favored system.

REFERENCES

1. R.C. Kainthla, O. Velez, G.H. Lin, N.J.C. Packham, M. Szklarczyk, J. Wass and J.O'M. Bockris, "Sporadic Observation of the Fleischmann-Pons Heat Effect," *Electrochim. Acta*, vol 34, (1989), pg 1315.
2. C.C. Chien, D. Hodko, Z. Minevski and J.O'M. Bockris, "On an Electrode Producing Massive Quantities of Tritium and Helium," *J. Electroanalyt. Chem.*, vol 33, no 8, (1992), pg 189.
3. J.O'M. Bockris, R. Sundaresan, Z. Minevski and D. Letts, "Triggering of Heat and Sub-Surface Changes in Pd-D Systems," *J. Fusion Technology*, vol 26, (1994), pg 267.
4. J.O'M. Bockris, D. Hodko and Z. Minevski, "The Mechanism of Deuterium Evolution on Palladium: Relation to Heat Bursts Provoked by Fluxing Deuterium Across the Interface," The Science of Cold Fusion: Proceedings of ICCF-2, Como, (1991).
5. S. Pons, M. Fleischmann, and M. Hawkins, "Electrochemically Induced Nuclear Fusion of Deuterium," *J. Electroanalyt. Chem.* vol 261, (1989), pg 301.
6. D.C. Borghi, *Nuovo Cimento, Savie Nova*, vol 1, (1943), pg 1.
7. C.L. Kervran, Proofs in Geology and Physics of Low Energy Transmutation, Malvine (Personal communication) 1973.
8. Kushi, Private communication to R.A. Monti, 1991.
9. P. Graneau, "Capillary Fusion," *J. Sci. Exploration*, vol 8, (1944), pg 428.
10. Milburn Miles, B.F. Bush, G.S. Ostrom and J.J. Lagowski, "Heat and Helium Production in Cold Fusion Experiments," The Science of Cold Fusion: Proceedings of ICCF2, Como, Italy, 1991, pg 363.
11. A.B. Karabut, Y.R. Kucherov, I.B. Savatimova, "Gamma-Spectrometry at Glow Discharge in Deuterium," Frontiers of Cold Fusion: Proceedings of ICCF3, Nagoya, Japan, 1992, pg 165.
12. R.T. Bush and R.D. Eagleton, "Calorimetric Studies of an Electrolytic Excess Heat Effect Employing Light-Water-Based Electrolytes of Some Alkali Salts," Frontiers of Cold Fusion: Proceedings of ICCF3, Nagoya, Japan, (1993), pg 405.
13. T. Mizuno and M. Enyo, "Formation of ^{197}Pt Radioisotopes in Solid State Electrolyte Threated by High Temperature Electrolysis in D_2 Gas," *Infinite Energy*, Sept-Oct 1995, pg 9.
14. J. Ohmori, et al., "Isotopic Distributions of Heavy Metal Elements Produced During the Light Water Electrolysis on Au Electrode," *New Energy News*, vol 3, no 2 (1995); *The Journal New Energy*, vol 1, no 2 (1996).
15. J. Dash, "Excess Heat and Unexpected Elements from Electrolysis of Acidified Heavy Water with Titanium Cathodes," *The Journal of New Energy*, vol 1, no 3, (1996).
16. E.A. Moelwyn-Hughes, *Physical Chemistry*, Pergamon, (1968).
17. M. Kubalka and B. Baranowski, "Diffusion Coefficients of Hydrogen and Deuterium in Highly Concentrated Palladium Hydride and Deuteride Phases," *Bet. Dun.- esell*, vol 78, (1974), pg 335. See also: S. Majorowski and B. Baranowski, *J. Phys. Chem. Solids*, vol 4, no 3, (1982), pg 1119.
18. P.K. Subramaniam, "Electrochemical Aspects of Hydrogen in Metals," in *Comprehensive Treatise of Electrochemistry*, vol 4, Plenum, (1981).

19. J.O'M. Bockris and Z. Minevski, "Two Zones of 'Impurities' Observed after Prolonged Electrolysis of Deuterium on Palladium," *Infinite Energy*, vol 5-6, (1996), pg 67.
20. H.J. Flitt, R.W. Revie and J.O'M. Bockris, "Hydrogen Evolution in Stress Corrosion Cracking," *Australian J. Corrosion*, vol 1, (1976), pg 4.
21. J.O'M. Bockris, W. Beck, M.A. Genshaw, P.K. Subramaniam, and F.S. Williams, "The Effect of Stress on the Chemical Potential of Hydrogen in Iron and Steel," *Acta Metallurgica*, vol 19, (1971), pg 1205.
22. J. Gittus and J.O'M. Bockris, "Explorations of Cold Fusion," *Nature*, vol 105, (1989), pg 339; see also, D. Hodko and J.O'M. Bockris, *Frontiers of Cold Fusion: Proceedings of ICCF3*, Nagoya, Japan, (1992), pg 342.
23. J.O'M. Bockris and Z. Minevski, *Infinite Energy*. See [19]
24. J.O'M. Bockris and A.K. Reddy, "Electrodes: More Fundamentals," *Modern Electrochemistry*, vol. 2, chapter 9, Plenum, (1970).
25. J. Szpak and P. Boss, "On the Behavior of Pd Deposited in the Process of Evolving Deuterium," *J. Analytical Chem.*, vol 302, pg 244, (1991)
26. D. Hodko and J.O'M. Bockris, "Possible Excess Tritium Production on Pd Codeposited with Deuterium," *J. Electroanalyt. Chem.*, vol 353, (1992), pg 33.
27. H.J. Flirt and J.O'M. Bockris, "Concerning Absorbed and Adsorbed Hydrogen On and In Ferrous Metals," *Int. J.H. Energy*, vol 7, (1982), pg 41.
28. J.O'M. Bockris and A.K. Reddy, Electrodeics," *Modern Electrochemistry*, vol. 2, chapter 8, (1976). See also [29].
29. J.O'M. Bockris and Z. Minevski, *The Science of Cold Fusion: Proceedings of ICCF2*, Como, Italy, (1991)
30. J.O'M. Bockris and S.U.M. Khan, *Surface Electrochemistry*, pg 345, Plenum, New York, (1992).
31. J.O'M. Bockris and T. Ottagawa, "Mechanism of Oxygen Evolution on Perovskites," *J. Phys. Chem.*, vol 87, (1983), pg 2960.
32. B.E. Conway and T.C. Liu, Discussion Meeting, Bunsen Society, Sept. 2, 1986.
33. J.O'M. Bockris and S.U.M. Khan, *Surface Electrochemistry*, pg 651, Plenum, NY, (1993).
34. R.J. Morrissey, *Metal Finishing*, vol 92, (1994), pg 258.
35. Y.E. Kim and A.L. Zubarev, "Optical Theorem and Effective Finite-Range Nuclear Interactions for Low-Energy Nuclear-Fusion Reactions," *Nuovo Cimento*, vol 1084, (1995), pg 1009.
36. J.O'M. Bockris and T. Ottagawa, *J. Electrochem. Soc.*, vol 131, (1986), pg 1984.
37. F.G. Will, K. Cedynska and D.L. Linton, "Possible Tritium Generation in Electrochemical Cells Employing Palladium Cathodes with High Deuterium Loading," *J. Electroanalyt. Chem.*, vol 360, (1993), pg 161.
38. E. Storms, "How to Produce the Posn-Fleischmann Effect," *Fusion Technology*, vol 29, (1996), pg 261; See also, *Infinite Energy*, vol 5,6, (1996), pg 77.
39. Z. Minevski, Thesis, "Studies of Protective Layers on Aluminum and Aluminum-Tantalum Alloy," Texas A&M University, (1995).
40. K. Shoulders, "Observations on the Role of Charge Clusters in Nuclear Cluster Reactions," *The Journal of New Energy*, vol 1, no 3, September, 1996.