The Alchemist's Dream Revisited

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It has just been in the last couple of months that I have found rekindled interest in the cold fusion story, dramatically introduced more than a decade ago by Stanley Pons and Martin Fleischmann[2], then of the University of Utah in Salt Lake City. My arousal came about primarily from a due diligence effort concerning, of all things, a neutron activation analysis (NAA) question posed to me in the detection of C-4 and Semtex explosives. The requirement to efficiently generate large fluxes of neutrons led to a review of George H. Miley's[3], work on Inertial Electrostatic Confinement (IEC) of a fusion plasma, a technique for generating neutron fluxes by electrically accelerating deuterium nuclei into deuterium plasma target nuclei, a reaction which produces ${}^{3}_{2}He$ and 2.45 MeV neutrons in a fusion reaction. The initial IEC stimulus for Miley's work would appear to have come from: (a) the much earlier work of Philo T. Farnsworth, the Father of Television, who invented a device referred to as the Farnsworth Fusor, the first such IEC device, and (b) a response to the early Pons and Fleischmann cold fusion announcements (discoveries). Miley has been an active worker in the general field of cold fusion type low energy nuclear reactions (LENRs) since the late 1980's. Unfortunately, the near universal boycott of the subject of cold fusion by the American Physical Society (with Bob Park[4] as their outspoken, but unofficial spokesman) and the U.S. Department of Energy has left Professor Miley in the uncomfortable position of pursuing his primary interests in the private entrepreneurial sector without major institutional support. A review of his recent publications as listed in the faculty section of the University of Illinois-Urbana web site[5] does not show a single reference to cold fusion or low energy nuclear reactions, only to the related IEC investigations; apparently his curriculum vitae has been sanitized for public appearance purposes.

The crux of the aversion to cold fusion or LENRs would appear to reside in a few simple facts. First, B. Stanley Pons and Martin Fleischmann made the early announcement at a press conference on March 23, 1989 at the University of Utah, that "Simple experiment results in sustained N-fusion at room temperature for the first time." In the following months the world reverberated with a flurry of activity to confirm these findings and to reap the rewards of a near infinite source of energy from a fuel source as abundant as seawater. In their experiments they were simply operating an electrolytic cell where the cathode material was palladium metal and the electrolyte contained a high concentration of heavy water (D_2O). Their cell, after operating without noticeable incident for some time, began to produce copious amounts of excess energy

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[2] Cf. F. David Peat, ***Cold Fusion***, Contemporary Books, Chicago Ill., 1990, pp.204. This reference provides an overview on the story of the cold fusion discovery and controversies which ensued.

[3] George H. Miley and John Sved, ***"The IEC—A Plasma-target-based Neutron Source",*** *Applied Radiation and Isotopes,* Vol. 48 No. 10-12, October-December 1997, pp. 1557-1561, Elsevier Science Ltd.

[4] Dr. Robert L. Park, professor of physics at the University of Maryland, and Director of Public Information of the American Physical Society. In his book, ***Voodoo Science: The Road from Foolishness to Fraud***, dismisses cold fusion at its very first mention.

5 http://www.ne.uiuc.edu/Faculty/miley.html

in the form of heat which Pons and Fleischmann could not explain by any chemical reaction kinetics. They concluded that the reactions thus formed must be nuclear fusion reactions. The scientific community responded with gusto, major emphasis being supervised by the national laboratories and the so-called "hot fusioneers" who have spent billions from the public treasury in the elusive search for a controlled thermonuclear reaction. If indeed the experiment was demonstrating a deuterium fusion reaction, then the signature products should be present: tritium, helium, high energy neutrons, and gammas. Some of these products were spuriously identified by various labs but at no time was the experiment repeatable. Generally speaking, however, these evidenciary products were not found with any regularity nor at significant levels. A USDOE Energy Research Advisory Board (ERAB) was formed to study the issue, some members of which were extremely biased individuals; one ERAB panelist (Professor William Happer of Princeton) actually stated, "Just by looking at Fleischmann and Pons on television you could tell they were incompetent boobs." Three premiere major laboratories at MIT, Caltech, and Harwell turned in negative reports and cries of "possible fraud", "scam", and "scientific schlock" rang out. The final outcome was to label the entire issue as voodoo science. The U.S. Patent Office would not entertain any patent application on cold fusion and the USDOE would not fund any programs hinting of cold fusion research. The follow-on research was forced to move abroad to Europe, Japan, and Russia, or locally to go underground so-to-speak. Major peer-reviewed scientific publications shunned reporting this type of work and as a result, several small start-up publications have heroically attempted to keep the fires of free-spirited intellectual pursuit burning e.g., *Fusion Technology* and *Journal of New Energy* carry the bulk of the papers during the last decade. It is noteworthy that *Fusion Technology* is an organ of the American Nuclear Society; that it prints any information on cold fusion may be a result of the fact that George Miley is editor of that journal.

The experiment that started all this flap was a very simple one, an electrolytic cell was constructed of palladium metal cathode and immersed in a heavy water (D_2O) electrolyte and connected to a power source which caused current to flow in the cell. After operation for some time the cell began to produce thermal energy at a rate that far exceeded any known chemical reaction potential. Fleischmann and Pons, in a major attempt to protect their findings and patent any resulting break-though, may have poisoned public acceptance and scientific peer review by withholding much vital information. As laboratories attempted to repeat the results of their experiments, chaos abounded. A closely related body of work carried out at Brigham Young University by Steven Jones also suggested cold fusion reactions but at rates far below those reported by Pons and Fleischmann. In the immediate period following the announcements, palladium futures skyrocketed and the Canadian Ontario Hydro heavy water plant on Lake Huron was flooded with requests and orders for heavy water. Spurious reports of fusion ash, helium, tritium, neutrons, etc. abounded; however, in the end no distinct signature of the deuterium-deuterium fusion reaction ever unambiguously surfaced, i.e. the 2.45 MeV neutron which should be present in massive quantities. More to the point, a large number of independent workers could not even demonstrate excess energy production.

There were, however, a few intrepid souls who continued their investigations into cold fusion, attempting to refine the method and process to achieve repeatability and to provide some meaningful basis for further investigation. George H. Miley was one such investigator and his effort provides a good starting point for my further discussions.

George H. Miley is a Professor of Nuclear Engineering and Director of the Fusion Studies Lab at the University of Illinois-Urbana. He has concentrated his efforts on cold fusion in a Thin-Film Low Energy Nuclear Reaction (LENR) Power Cell[6]. Direct experience in this cell, its operation and continued refinement have cleared the way for meaningful physical analysis as we shall see in the following paragraphs. Professor Miley, et. al., has contributed a number of important points to the knowledge data base:

- Palladium impurity contamination and lattice defects can make repeatable experiments very difficult; hydrogen embrittlement can lead to crack formation and propagation.
- Palladium is not the only metal which can be used, nickel and titanium are also much less expensive alternatives.
- Deuterium is not a mandatory ingredient, normal light hydrogen can also be effectively employed in cold fusion cells.
- 1-molar lithium sulfate electrolyte is a preferred solution but no physics is directly available to justify this choice.
- Contamination of the electrolyte can easily build up in the metallic lattice and obscure results.
- The use of thin films of metal deposited upon glass substrates leads to much better control of the experiment and, in turn, in conjunction with an H/metallic atom ratio of 0.95 within the lattice, extremely repeatable excess power production can be initiated and sustained.

Miley et. al. have deposited thin film metallic layers on glass substrates, either singly or in mixed layers, using metallic atoms (X) of nickel, palladium, and/or titanium and have arranged these as electrodes in a typical electrolytic cell using a Li_2SO_4 in H_2O or D_2O electrolyte. Once the proton loading of the matrix H/X atomic ratio reaches values of 0.95, power levels in the cell exceed any predictable values based upon chemical reactions including the effect of energy storage after "pumping" the metallic lattice. The excess energy production has continued for periods in excess of 300 hours at levels twice that of the input energy power level. Miley's use of thin films has pretty much removed the issue of non-repeatability experienced by the early Pons and Fleischmann experiments. Higher excess power levels are possible; however, it would appear that thermal stresses tend to destroy the electrode matrix prematurely causing cell shut down. Throughout the excess power generation interval of the operating period the cell demonstrates no unusual nuclear radiation of neutrons or gamma rays. Some researchers, however, have reported the exposure of x-ray film stored nearby. Hot fusioneers have argued that if nuclear fusion of deuterium is taking place then we should expect a 2.45 MeV neutron with a ${}_2^3He$ nucleus left in the debris or a 5.4 MeV gamma with ${}_1^3H$ and ${}_1^1H$ as residue. These neutrons/gammas are not normally encountered. Perhaps the most revealing data comes from the Miley group's painstaking efforts to unfold some very unorthodox physical behavior of the cell.

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[6] George H. Miley, Giovanna Selvaggi, Andy Tate, Maria Okuniewski, Mike J. Williams, D. Chicea, "***Experimental Status and Potential Applications of a Thin-Film Low Energy Nuclear Reaction (LENR) Power Cell", P***roceedings of ICONE 8, 8th International Conference on Nuclear Engineering, April 2-6, 2000, Baltimore, MD, copyright ASME 2000, 13 pp.

Due to the nature of the thin film sputtering techniques it is relatively easy to control the impurities in the thin film. Using very high purity thin films also lends itself to post mortem analysis of the thin film material following a successful power generation run. Miley analyzed material before and after using Secondary Ion Mass Spectrometry (SIMS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This technique allowed analysis of total bed composition and hot spot compositions. The key findings are most impressive:

- New mass numbers (elements) were found in the matrix exceeding the initial concentration by orders of magnitude or more,
- New elements showed statistically significant deviations from natural abundance,
- Reaction products have mass numbers lying well above and below the mass number of the metallic coating,
- Reaction rates as high as 10^{16} atoms/s·cm^3 are obtained for high yield elements,
- The highest yield elements fall into mass bands around A~ 22-23, 50-80, 103-120, 200-210,
- These high yield element bands are similar for the various metal coatings (Ni, Pd, and Ti), but the relative yields in each band depend on the metal,
- The mass band peaks for each metal occur in an ordered fashion that can be associated with a magic number sequence,
- High yield elements generally exhibit statistically significant shifts from natural isotopic abundance, while select low yield elements have even larger shifts,
- The reactions and products release little high energy radiation but do exhibit lower energy (≤ 20 keV) X-ray and/or beta emission as measured by removing the electrodes after a run.

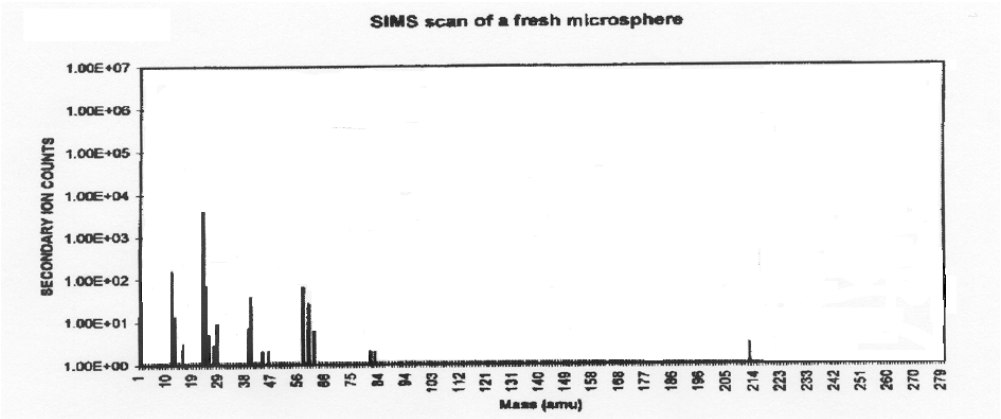


Fig. 3a. Typical low resolution SIMS scan (before the run).

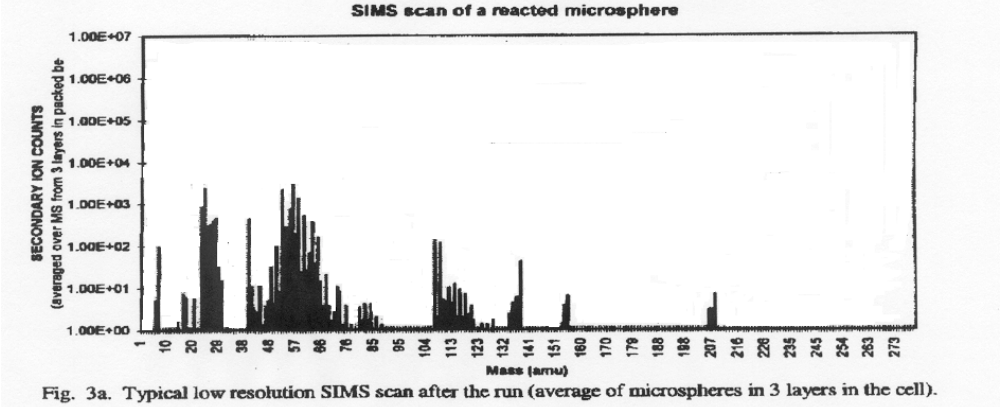


Fig. 3a. Typical low resolution SIMS scan after the run (average of microspheres in 3 layers in the cell).

I have included here a scanned copy of Miley's Figure 3 from the Miley and Patterson [1996] paper[7] to provide some sense of the spectacular nature of the cell performance. This figure reports results from a slightly different Patterson power cell which uses 1-mm polystyrene plastic micro-spheres coated with multi-layers of thin metallic film in a total thickness of about 650 Å. The figure shows Secondary Ion Mass Spectrometry (SIMS) plots of mass number for spheres before and after electrolytic operation in the power cell. SIMS uses an ionized oxygen beam to sputter away material from the target which is subsequently analyzed, thus there is a complicated calibration of the SIMS apparatus to obtain good quantitative information. In this case the polystyrene spheres were coated with sputtered nickel to a thickness of about 650 Å. Platinum screens and titanium electrodes were present in the cell. In the first low resolution scan of virgin spheres prior to any cell operation one can easily see the group of isotopes of nickel at mass numbers 58-62. Scattered in with the primary nickel is, of course, evidence of contaminants from other sources. A detailed analysis of the two scans is well beyond the scope of this note, but it should be instructive to note the difference in the two scans taken under identical conditions. Miley and Patterson actually describe contaminants measured using neutron activation analysis (NAA), field emission electron deposition (x-ray) microscopy (EDX), as well as the SIMS data. Contaminants of magnesium, aluminum, silicon, sulfur, silver, chromium, iron, copper, vanadium, cobalt, and zinc were also detected. The interesting point to follow is the change in this isotopic distribution following a typical operational run of the cell. The second SIMS scan is of a typical micro-sphere after a 310 hour operation of the cell in during which time an excess power of 0.5 watt was observed. It is quite evident that a whole host of new materials with vastly differing mass numbers is inhabiting the scene. While Miley et. al. did not directly point out the possibility of multiple ionization states that could explain many of the lower mass numbers shown, it is important to consider that even if this was happening, the multiple ionization is showing up as a result of new elemental mass numbers above that of the nickel isotope series. Both plots were presumably taken from identical SIMS scans. I would propose one additional observation. The center of mass of the two distributions is significantly different. The before scan has a mass center in the vicinity of 28. The after scan has a center in the vicinity of 66. I will discuss the importance of this a little later.

Miley proposes that the process which occurred to fit the data goes as follows:

> Consider, for example, the complex nucleus (X*-313) of mass A ~ 313 identified from the fission type yield shape of the reaction products from Run #8 lying at A=103 -210 (Miley, 1998[8], Miley, 1997[9]). The formation 23n* + 5 Ni-58 = X*-313 corresponds to 8.2 MeV/nucleon for the reactants (N* represents a virtual neutron created via an e + p reaction, cf. Stoppini, 1998[10]). Further, if the yields of all experimentally observed products lying in the mass range A=103-210 are multiplied by their appropriate binding energies and divided by the total number of nucleons involved, a value of 8.1 MeV/nucleon is obtained. This suggests a net increase in binding energy of 0.1 MeV/nucleon for the complex, i.e. a heat release during formation of the complex. Additional en-

[7] Miley G. H. and Patterson, J. A., "***Nuclear Transmutations in Thin-Film Nickel Coatings Undergoing Electrolysis"***, *Journal of New Energy*, Vol. 1, No. 3, pp. 5-30, 1996.

[8] G.H. Miley, ***"Possible Evidence of Anomalous Energy Effects in H/D-Loaded Solids Low Energy Nuclear Reactions (LENRs)",*** *Journal of New Energy*, Vol. 2 (3-4), Winter 1997, pp. 6-13.

[9] G. H. Miley, ***"Characteristics of Reaction Product Patterns in Thin Metallic Films Experiments,"*** *Proceedings, ASTI Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals*, Asti, Italy, Societa Italiani di Fisica, Bologna, Italy, Nov. 27-30, 1997.

[10] G. Stoppini, "Nuclear Processes in Hydrogen Loaded Metals", Fusion Technology, Vol. 34, (1), p. 81, 1998.

ergy release occurs in the subsequent fission of the complex, resulting in the overall prediction of ~1.9 W/cc excess power noted earlier.

This summary statement is certainly illuminating and speaks of processes for which we have no fundamental physical theory with which we might further investigate. Miley is invoking the existence of at least 28 virtual neutrons which appear out of the false vacuum of space-time and to carry it one step further, is proposing that five nickel nuclei can somehow break the Coulomb repulsive barrier and fuse together. This action is then followed by a fission into stable daughter products. Now this is a fairly preposterous proposal. Invoking virtual neutrons in addition to overcoming the Coulomb repulsive barrier of nuclei the size of the nickel nucleus is at least far-fetched; however, far-fetched and preposterous is just what is required. How can one possibly explain the difference between his before and after mass distributions without new physics? At least two observations can be made without risking the accusation of practicing voodoo science. First, **transmutation of the elements is clearly visible** unless one wishes to invoke the creation *ad nihilo* of the new ingredients. Second, the shift in the center of mass of the two distributions is significant enough to require a source of new neutrons[11]. The mass of 28 amu is indicative of a normal neutron/proton ratio of about 1:1 whereas the value of 66 amu requires a neutron/proton ratio of about 1.2:1. Clearly, conservation of nucleon type cannot explain the neutron enrichment of the reaction products. **Neutrons must be produced in the operation of this cell.** The most logical source of neutrons is not from the virtual space of the false vacuum, but from the material resident in the cell and the metallic lattice, i.e. hydrogen nuclei and a flood of electrons. (Miley quietly alludes to the "virtual neutron created via an e + p reaction" without much further comment. This is unfortunate in that I believe this is the focal point for the entire phenomenon.)

This is the point where I diverge from a simple review of Miley, Pons, Fleischmann, et. al. and begin related discussion; however, I will endeavor to introduce a few more historical perspectives before hypothesizing further.

Some twenty eight years ago Messrs. Tompkins and Bird dedicated a chapter in their book[12] ***The Secret Life of Plants*** to the "Alchemists in the Garden" wherein it was shown that biological organisms appear to be able to transmute the elements. Many different transmutational occurrences were discussed, but one sticks in my mind most clearly. Louis Kervran, when a young Breton schoolboy, had observed chickens pecking about the barnyard for micaceous specks of material which were not evident in the gizzard when the chicken ended up in the cooking pot. The chicken flocks produced eggs with calcareous shells, though they apparently had not ingested any calcium from land which was totally lacking in limestone. Sometime later when Kervran was a graduate engineer and biologist and reading of the celebrated French chemist, Louis Nicolas Vauquelin, who "having calculated all the lime in oats fed to a hen, found still more in the shells of its eggs," Kervran decided to take matters into his own hands and repeat this experiment. He fed chickens on oats alone where the calcium content had been carefully measured. He then checked the calcium content in both the eggs and feces issuing from the chicken and found that the hens were producing four times as much calcium as they had ingested.. When denied access to all known calcium sources he noted with shock that the eggs continued to come

[11] I argue that the center of mass of the "before" distribution is around 28 amu (representative of $_{14}Si^{28}$) while the "after" distribution is easily greater than 65 amu characteristic of $_{30}Zn^{66}$.

[12] Peter Tompkins and Christopher Bird, ***The Secret Life of Plants***, Harper and Row, New York, 1973, p. 274-291.

out with nice hard shells on them. Acting on an impulse he removed potassium[13] from their diet as well. Removal of the potassium while withholding dietary calcium resulted in the incomplete development of the egg shells within a period of about four days. Kervran then reintroduced potassium into the chicken's diet and the very next egg returned to the hard calcareous shell. Kervran concluded that the chicken must somehow convert potassium to calcium in a biological transmutation reaction. Other workers have also found similar types of elemental inconsistencies when working with plants: algae, clover, trees, seeds, chicks, etc. The Hanoverian baron, Albrecht von Herzeele, studied seeds sprouting in distilled water and showed that the original content of potash, phosphorus, magnesium, calcium, and sulfur quite inexplicably increased in the plants issuing from the seed. Von Herzeele noted that "plants seemed to be able to transmute, in alchemical fashion, phosphorus into sulfur, calcium into phosphorus, magnesium into calcium, carbonic acid into magnesium, and nitrogen into potassium.." These studies came to the attention of Pierre Barranger of the Ecole Polytechnique de Paris, then director of the inorganic chemistry laboratory. Barranger arranged a series of experiments which lasted nearly a decade. The announcement of his results in ***Science et Vie*** (1959) stated, "My results look impossible, but there they are. I have taken every precaution. I have repeated the experiments many times, I have made thousands of analyses for years. I have had the results verified by third parties who did not know what I was about. I have used several methods. I have changed experimenters. But there's no way out; we have to submit the evidence: plants know the old secret of the alchemists. *Every day under our very gaze they are transmuting the elements.*"

Nearly one half century ago Margaret and Geoffrey Burbidge, Willie Fowler, and Fred Hoyle (B^2FH) published their now famous seminal stellar nucleosynthesis paper[14] which painstakingly detailed the various processes taking place within the heart of a star to produce essentially all the heavy elements beyond helium and hydrogen. They describe several processes for nucleosynthesis:

- Hydrogen burning - primary fusion cycle reactions to produce He^4.
- Helium burning - synthesis of carbon from helium and by further α addition to produce O^{16}, Ne^{20}, and perhaps Mg^{24}.
- α process - progressive addition of alpha (α) particles successively added to Ne^{20} to produce four-structure nuclei Mg^{24}, Si^{28}, S^{32}, A^{36},$Ca^{40,}$ and probably Ca^{44} and Ti^{48}.
- e process - an equilibrium process which describes the production of the iron peak synthesis: Fe, V, Cr, Mn, Co, and Ni.
- s process - long time scale ($\sim 10^2$- 10^5 years) neutron capture with gamma radiation (n, γ) process which produces isotopic abundance peaks in the range of $23 \leq A \leq 46$ and a considerable portion of the isotopes in the range of $63 \leq A \leq 209$. The s process produces the abundance peaks at A= 90, 138, and 208.
- r process - process of neutron capture on a very short time scale (0.01 - 10 sec) for beta decay between neutron captures (n,β). The neutron captures occur at a rapid rate compared to the beta decays. This mode is responsible for production of a large number of isotopes in the range $70 \leq A \leq 209$ and also for the synthesis of uranium

[13] Mica is a monoclinic phyllosilicate which contains potassium and calcium in the chemical assay, generally described by the formula $(K,Na,Ca)(Mg,Fe,Li,Al)_{2\text{-}3}(Al,Si)_4O_{10}(OH,F)_2$. Perhaps the memory of chickens feeding on mica prompted his guess on potassium.

[14] E. Margaret Burbidge, Geoffrey R. Burbidge, William A. Fowler, and Fred Hoyle, *"Synthesis of the Elements",* ***Review of Modern Physics 29,*** 547-650 [1957].

and thorium. The process may also be responsible for some light element synthesis, e.g., S^{36}, Ca^{46}, Ca^{48}, and perhaps Ti^{47}, Ti^{49}, and Ti^{50}. The r process produces abundance peaks at A= 80, 130, and 194.

- p process - proton capture with the emission of gamma radiation (p,γ) or the emission of a neutron following gamma ray absorption (γ, n), which is responsible for the synthesis of a number of proton rich isotopes having low relative abundance compared with neighboring normal and neutron-rich isotopes.
- x process - a poorly described process which produces low mass deuterium, lithium, beryllium, and boron . A characteristic of this process is the fact that all are very unstable at stellar temperatures which suggests that they are produced in regions of low density and temperature.

Some 272 stable and 55 naturally radioactive isotopes occur on earth. Man has also been able to produce 871 radioactive isotopes and the number is increasing. Thus the total number of known nuclear species numbers 1,200 with 327 species known to occur in nature. As B^2FH state in their introduction, "Prompt nuclear processes plus the slow beta reactions make it possible in principle to transmute any one type of nuclear material into any other even at low energies of interaction." A review of the list of available processes shows that by and large, a ready source of neutrons is all that is needed to produce a very wide variety of elemental isotopes. Modern science asserts that the appropriate environment for neutron production is deep within the stellar interior where hydrogen is fully ionized amidst a sea of screening electrons and forced to very small separation distances by the tremendous gravitational overburden of matter. Something within the physics of this environment produces neutrons from protons and electrons. Something within the physics of this environment also promotes large scale generation of heavy nuclei from much lighter ones. The B^2FH theory would relegate the bulk of this process to a set of neutron processes, the slow (s) process which allows nuclei to capture neutrons followed by prompt gamma emission with nuclear buildup until such point as the nucleus reaches the point of maximum stability. Further neutron capture results in a radioactive isotope which decays by beta emission and a gamma resulting in nuclear elemental transmutation. This is not the only process however. Should neutron capture proceed at a rapid (r) process it may very well be possible for the nucleus to acquire several more neutrons before the random beta decay occurs at the point of maximum stability. The s process is thought to be predominantly responsible for elements in the mass range of 23-46. The s-process also contributes to elements with mass number above 46 all the way up to 208 and the lead, bismuth, polonium group of elements. The very heavy elements are thought to be produced by the r-process which is responsible for major elemental synthesis in the mass range of 70 up through thorium, uranium, and beyond.

Viewing momentarily the neutron capture process as a likely candidate for the transmutation reactions taking place in the Miley experiments we note his claim that "so far attempts to measure nuclear radiation emission-neutrons, gammas, or x-rays-during cell operation have not detected measurable quantities above background [Miley, Fall 1996, p. 13]." A cursory examination of the Brookhaven National Laboratory National Nuclear Data Center on Thermal Neutron Capture Gamma-rays[15] for all of the stable nickel isotopes which are present in the thin film experiment indicate gamma production for the five most intense emissions from each of the eight nickel nuclei present in natural and first generation neutron capture nuclei to fall in the range

[15] http://www.nndc.bnl.gov/wallet/tnc/capgam.shtml, see tables for Ni858 (68.077%), Ni-59,Ni-60 (26.223%), Ni-61 (1.14%), Ni-62 (3.634%), Ni-63, Ni-64 (0.92%), Ni-65.

from a low of 63.60 keV for Ni-64 to a high of 11.386 MeV for Ni-59. Miley claims to have observed reaction rates on the order of $3x10^{11}$ reactions/second. Surely if r or s process neutron capture were taking place in a traditional sense then they should have observed gamma rays in large measure. If proton fusion were taking place then we would observe the missing gammas and neutrons that the hot fusioneers having been claiming are missing. Taking Miley at face value, he is claiming a model which requires twenty three virtual neutrons in conjunction with five nickel nuclei to fuse into a massive 313 amu super-heavy nucleus (23n* + 5 Ni-58 = X*-313) which subsequently decays into appropriate daughter products fitting the magic number peaks observed. No Standard Model promises anything remotely resembling this process. To make matters worse for modern theory is the recent observation of the distribution of gold in the stars. Where did the gold in your jewelry originate? No one is completely sure. The relative average abundance in our Solar System appears higher than can be made in the early universe, in stars, and even in typical supernova explosions. Some astronomers now suggest that neutron-rich heavy elements such as gold might be most easily made in rare neutron-rich explosions such as the collision of neutron stars[16]. It would appear that there must indeed be other processes at work within the universe, and our physical world, that can and do transmute the elements.

In my mind's eye the missing consideration appears to reside in the issue of closely spaced atomic and nuclear processes. The reactions alluded to by the cold fusioneers acknowledge the buildup of massive nuclei on both sides of the parent peak in the mass distribution. The fuel would appear to be the parent metal in the lattice as well as adjoining matter in the electrolyte, etc. In order to increase the atomic number of the daughter materials it is necessary to have a new and fresh source of neutrons. We note that the proton/neutron (p/n) ratio in helium is precisely 1:1. At the peak of the nuclear binding energy curve represented by the stable elements of Fe, Co, and Ni we have a p/n ratio of approximately 1:1.2. At the extreme end of the mass distribution we find U-238 boasting of a 1:1.59 ratio. Clearly, as we move up the scale of the elements we must come up with freshly made neutrons. This is in contrast with a requirement to conserve neutrons...new neutrons are required. The lighter elements do not have the available inventory. If the Miley proposal for fusion of metal nuclei is to be treated seriously then we must also find a way to overcome the Coulomb repulsion barrier between nuclei and like charged particles. Fusion of metallic nuclei is fraught with a degree of intellectual complexity beyond the prowess of this author. The only other option, however, is to allow the production of a prodigious and copious quantity of neutrons which are sucked up by surrounding nuclei with near unit efficiency.

Unfortunately, neither B^2FH or any other investigator has ever come up with a proposition concerning neutron synthesis. We know only that neutrons may escape from the nucleus under various conditions of nuclear excitation and that neutrons in the wild, free so-to-speak, decay into an electron and proton along with the enigmatic antineutrino. The Standard Model would have a neutron with an up (u) and two down (d) quarks, udd, decay by a route that involves the conversion of a down quark into an up quark and a virtual W- boson particle. From the virtual W- boson emerges an electron and an antineutrino. In my own simplified perspective, the neutron beta decays into a proton and an electron. The half-life of a free neutron[17] is 614.8 s for those who believe the Ernest O. Lawrence Berkeley National Laboratory scientists or 890 s

[16] Astronomy Picture of the Day, April 5, 2001, http://antwrp.gsfc.nasa.gov/apod/ap010405.html
[17] http://isotopes.lbl.gov/isotopes/decay/parent/nn_iso.htm

for those who have a stronger belief in the IUCF Weak Interactions Group[18] at Indiana University.

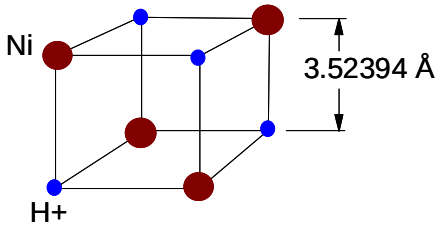
A fundamental consideration in an analysis of an LENR as described by Miley et. al. is the role of atomic spacing. Consider for a moment the phenomenon of muon catalyzed fusion. A molecule of diatomic heavy hydrogen (deuterium) whose electron complement has been replaced by muons experiences a covalent bond which is shortened by a factor of 300 due to the muon mass of 300 m_e and a normal electronic charge. This close spacing is such that the probability of tunneling behavior of one nuclei into the other is increased significantly to the point that fusion does actually occur, i.e., quantum tunneling overcomes the Coulomb barrier between the two nuclei. Consider now close spacing of two attractive bodies, the electron and proton, in non-atomic behavior. A single ionic proton has entered the metallic lattice and is immersed in a stream of conduction electrons moving through the lattice spacing. There is every possibility that an electron will be found at a very close approach distance to the proton, a spacing much less than the first Bohr orbit radius. Electron capture is certainly one naive consideration in this configuration. Should the electron actually have the kinetic energy to make up the balance of the rest mass of the neutron, then it occurs to this author that we should consider such an alternative. The factor that makes this such an appealing consideration is the simple fact that LENR type reactions do not begin to appear with repeatable results until the proton complement is high enough to effectively change the lattice geometry, i.e.; double the lattice nuclear occupancy.

Curiously, the actions of the electron (e^-) and the proton (p^+) have long violated any classical sense of good behavior. The mere fact that the single electron rotating about the lone proton in a hydrogen atom does not spiral into the proton thereby annihilating all evidence of charge is the cornerstone of quantum theory. We are led to believe that the de Broglie wavelength of the electron in the first Bohr orbit of the hydrogen atom is precisely equal to $2\pi r_H$ where r_H represents the radius of the first Bohr orbit (~0.528 Å). Thus a smaller radius is incompatible with an integral number of de Broglie wavelengths which complicates any standing wave type of analogy. Of course if we increase the charge on the nucleus, the radius of the first principle orbit decreases proportionately wherein for hydrogenic atoms (single electron atoms) the first principle orbit varies as r_q/Ze^2 where Z represents the charge on the nucleus (atomic number) and r_q represents the respective radius for charge q. This fact has been verified in the spectra of singly ionized helium, doubly ionized lithium, triply ionized beryllium, etc. In other words, the Coulomb force between the nucleus and the electron has been enhanced by a factor of Z and an entire family of calculations for radius, speed, energy, and photon frequency is realized. Presumably this relationship should hold indefinitely; however, certain practical considerations should apply. Should the orbit trajectory approach the nuclear surface we would certainly expect this relationship to break down. According to the simple scaling relationship even a hydrogenic uranium atom would have a first principal radius of about 0.006 Å (0.53 Å /92), a value which is still 750 times larger than the nucleus (8×10^{-16} m or 8×10^{-6} Å). But at what point, we may ask, does this relationship break down forcing the electron to do something entirely out of the ordinary?

The evidence surveyed to this point suggests that the "out of the ordinary" experience is for the electron is to combine with the proton in an entity which is known to us as a neutron. This state is not, however, at some preposterous energy level, unattainable in practical experience. It is a state which evidence suggests is well within the normal sphere of atomic metal lat-

[18] http://www.iucf.indiana.edu/~drich/life.html

tices and many organic molecular species. We know it is within the realm of stellar interior particle spacing. The suggestion that the formation event does not occur until the H/X proton to metal lattice atom ratio approaches unity suggests that a close spacing of protons within the lattice must have something to do with the problem.



It is a curious observation that the requirement that the H/X ratio be approximately unity is exactly the requirement necessary to fill out the corner regions of the face centered cubic nickel lattice as shown in the figure. Consider for the moment that when this proton requirement is not met, there is ample room for the conduction electrons in the electrolysis cell to stream around the nickel nuclei at the vertices shown occupied by the hydrogen nuclei. The outermost electron shell of nickel extends outward from the nucleus for about 1.25 Å. The atomic radius of an hydrogen atom is on the order of 0.78 Å. This leaves a zonal band of about 1.5 Å in which the conduction electrons can flow unhindered by the Ni atom or the H nucleus before unexpected things can begin to happen. First, let us consider that this hydrogen atom is not locked into a crystalline lattice nor is it bound in a chemical bond. It is being buffeted about in a vast sea of electrons, each one of which is attracted to a bare hydrogen nucleus. Without these H^+ ions in the corners, the electron sea has a massive free conduction zone on the order of 4.5 Å. Now, it is only a modest proposal that the probability of finding an electron within a distance much less that the first Bohr orbital radius of hydrogen is quite high under these conditions. Furthermore, electron acceleration in these regions is also quite high. Potential differences greater than 50 kV abound in these regions and if fractures or cracks develop in the film, then even higher potentials can develop. The preparation of multi-layers of alternating metallic films has been shown to enhance cell performance and this most certainly increases the electrical potential difference available at the lattice interface. It is worthy of mention that if an electron can develop 782 keV energy in its trek through this maze, then it has the energetic potential to form a neutron in a collision with a proton provided conditions do not allow radiation. Admittedly, this statement takes more than a little liberty with our present understanding, but, our present understanding is also inadequate to attack the problem.

The reference to 783 keV may need some justification. Working from the masses of the free electron, proton, and neutron as most recently published by the National Institute of Standards and Technology (NIST) and reported here for reference we find compute an energy balance for a proton and energetic electron interaction:

$$m_p = 1.67262158(13)\text{x}10^{-27}\text{kg}$$
$$m_n = 1.67492716(13)\text{x}10^{-27}\text{kg}$$
$$m_e = 9.10938188(72)\text{x}10^{-31}\text{kg}$$

$$m_p + m_e + \Delta m \rightarrow m_n$$

$$\Delta m = 1.394642 x 10^{-30}\, kg$$

$$\Delta mc^2 = 1.394642 \times 10^{-30}\, kg \cdot 2.998 \times 10^8\, m/s^2 = 783.4 keV$$

The mass of a proton added to the mass of an electron does not add up to the mass of a neutron. As a matter of fact, the neutron is heavier by an amount equal to 1.394642×10^{-30}kg which is equivalent to the mass of about 1.4 electrons (0.7834 MeV). From a consideration of electrical charge, the electrical neutrality of the neutron can only justify the union with a single electron and one proton. Thus there is something else involved in the structure of the neutron. Reversing the Standard Model process of neutron decay to form a neutron under controlled conditions defies my powers of description, i.e. the interaction of electrons and protons through the weakly interacting W particle is not something I am capable of describing. Suffice it to say, the energetics of the situation suggest that neutron production is an endothermic energy absorbing event which results in the union of an electron and a proton together with a stored energy of about 783.4 keV. Thus, the creation of the neutron requires an energy of about 0.8 MeV which subsequently is released ten-fold (8.6 MeV) in a neutron capture process by the metallic nucleus.

Our current state of knowledge says that neutron capture by a nucleus should result in excited energy state in the nucleus, the end result of which is a photon emission or decay. The published photon energies in thermal neutron capture experiments cover a spectrum of values ranging from 2.3 keV to 11.386 MeV for all elements. Nickel prompt gamma energies range from 252 keV to 11.386 MeV. There are at least two mechanisms which have been proposed which can absorb the excitation energy without prompt gamma emission: the metallic lattice vibration due to phonon absorption proposed by the late Julian Schwinger[19], and a pre-neutron hydrino formation mechanism introduced by Randell Mills in his hydrino model[20]. Schwinger argues that the missing energy represented by the prompt gammas resulting from neutron capture can be explained by lattice vibrational energy from phonon generation. Mills has a far greater reaching theory which is of great interest. He proposes that there are energy states available to the electron in the first principal orbit of the hydrogen atom that are the equivalent of fractional principal quantum numbers comparable to the orbits of other hydrogenous atoms (single electron). This concept should easily fly in the face of the quantum theorists except for the fact that Mills has shown the existence of radiation emanating from precisely those energy states or levels and has developed a power cell using precisely such a hydrino hydride of potassium ($KH\ KHCO_3$) which has an electrochemical binding energy of 22.8 eV, fifteen times higher that the traditional 1.5 volt cells of the alkaline battery. A review of Mills' work is fully the subject of another note or notes; suffice it to say he has prepared a massive tome of a work entitled ***The Grand Unified Theory of Classical Quantum Mechanics*** which is available for download at his web site (http://www.blacklightpower.com) or from Amazon.com as a Technomic Publishing Company book. I have not read this work in its entirety, much less study to the extent of developing a full understanding. I have however corroborated his calculations on stellar solar hydrogen emission wavelengths resulting from novel electron transitions which are previously unexplained or assigned. In other words, his arithmetic is correct, his physics is in limbo. The point to note from any dialog on Mills is that an entirely new and different approach to the understanding of the hydrogen atom is available and may shed some light on the neutron formation mechanisms.

Neutron production is not the only mechanism at work in the Miley experiments. The primary metallic lattice nuclei are being consumed, i.e., the concentration of primary nickel is

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[19] http://www.mv.com/ipusers/zeropoint/IEHTML/FEATURE/FSETS/SchwingerIss1set.html, "***Cold Fusion Theory: A Brief History of Mine***", Julian Schwinger, as published in Infinite Energy Magazine, Issue 1 March-April, 1995, p. 10.

[20] http://www.blacklightpower.com/pdf/technical/Schrodinger%20Paper%205_24_00_W.pdf, Randell L. Mills, ***The Hydrogen Atom Revisited***, Blacklight Power Inc., Cranbury, NJ.

decreasing as other elements and mass numbers increase. The experiment is, in truth, creating neutrons, converting heavy nuclei, and in the process is liberating energy. The energy liberated is more than a normal chemical reaction can provide and somewhat less than normal hot thermonuclear fusion reactions. The fact that electrode material is being consumed is better illustrated in the work of Mizuno[21] et. al. as shown here in scanned plot of energy dispersive x-ray spectroscopy (EDX) on palladium electrodes before and after operating the electrolysis cell. The before and after plot is shown here as Mizuno's Figure 1. The reduction in the EDX count on palladium of about 700,000 before electrolysis compared with a count of 120,000 after the run with essentially no other elemental spikes before the run is quite illustrative. The electrode after the run shows strong evidence of platinum, tin, titanium, chromium, iron, copper, and lead in the energy range of ~2-13 keV. While this simple plot does not in itself take cognizance of the great difficulties encountered in contamination, etc., it is an extremely graphic display of the introduction of new elements at the expense of the original palladium. This graph is representative of the alchemists dream; the metallic element has been transformed into precious platinum along with other metals. The fact that palladium is actually a more precious metal than platinum[22] should not daunt our enthusiasm. We could also use nickel or titanium to achieve comparable end results.

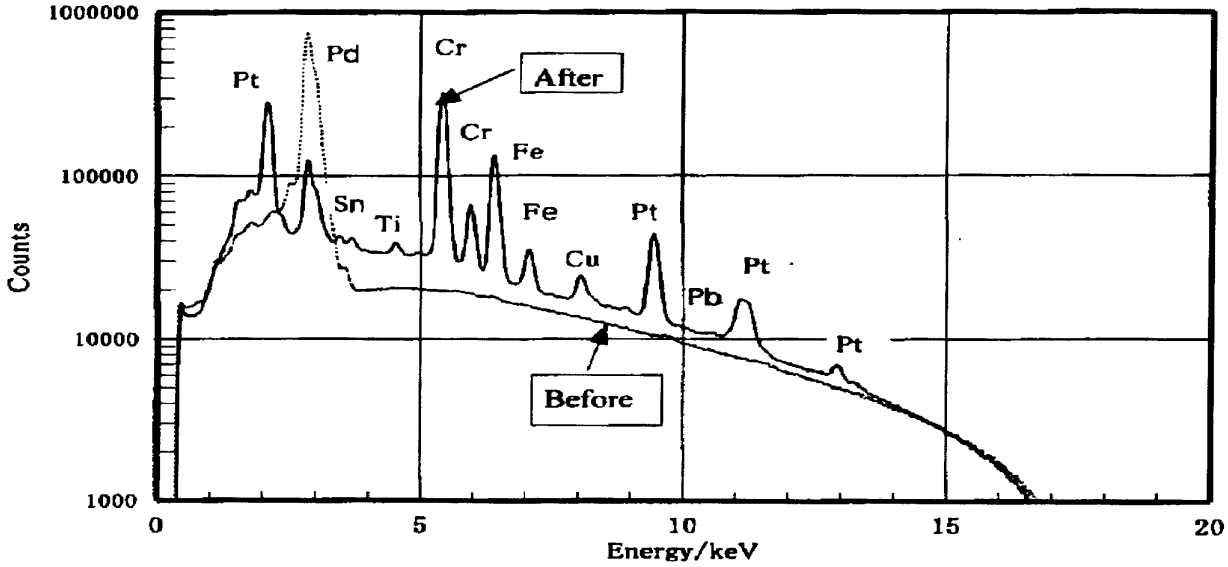

Fig. 1. EDX spectra from the Pd rod before and after the electrolysis.

Scanned Mizuno et. al. Figure 1

[21] Tadahiko Mizuno, Tadayoshi Shmori, and Michio Enyo, "*Isotopic Changes of the Reaction Products Induced by Cathodic Electrolysis in Pd*", ***Journal of New Energy, Vol. 1, No. 3***, Fall 1996, pp 31-45.
[22] The Gold Central Real Time Spot Price Index for May 22, 2001 indicates Pt at $626.50 and Pd at $670.50.

My intent here is not to solve the puzzle of what is transpiring in these most unusual experiments; it is, however, an attempt to set the stage for further study. There is a clear suggestion that the alchemist's dream has been fulfilled. The existence of new elements transformed from the old is quite clear from even a cursory view of the published evidence. The evidence that has not been published is very likely even more compelling. There is also the modest suggestion that a new source of energy is available from these reactions.

Table 1 is a tabulation of the energetics involved in a single thermal neutron capture event for 100 atoms isotopically distributed according to the known natural abundance for nickel. Nickel is chosen to be representative of the Miley and Patterson electrolytic cell material. The non-existence of neutrons outside of the electrolytic cell coupled with the observation that the mass distribution of the electrode material following a run requires the generation of neutrons forces the conclusion that the thermal neutron capture cross section of the nickel lattice atoms is quite high. In other words, if neutrons were produced and not observed outside of the cell, then they must have been absorbed. The table shows the atomic number (Z), the nuclear mass number (A), and the neutron number (N). The series of isotopes spanning the range of the naturally occurring ones are shown along with the natural abundance. The nuclear mass is as computed from Möller[23] et. al. Möller reports the nuclear mass in GeV instead of amu as reported here and recommends the conversion factor 931.5014 MeV/amu. The nuclear mass is developed from the experimental atomic mass less the electron inventory and the electron to nucleus binding energy.

Table 1 - First Generation Neutron Capture Energy Statistics for Naturally Occurring Nickel

Z	A	N	Natural Abundance (%)	Nuclear Mass (amu)	Mass+n (amu)	Mass Gain/Loss (amu)	Energy Gain/Loss (MeV/nucleus)	Group Gain (MeV)	Total Nucleons
28	58	30	68.077	57.91998	58.92864	0.00966	8.99823	612.57277	4017
28	59	31		58.91898	59.92765	0.01223	11.38752	0.00000	0
28	60	32	26.223	59.91542	60.92409	0.00839	7.81896	205.03665	1600
28	61	33	1.14	60.91569	61.92436	0.01138	10.59668	12.08021	71
28	62	34	3.634	61.91298	62.92164	0.00734	6.83717	24.84627	229
28	63	35		62.91430	63.92297	0.01037	9.65680	0.00000	0
28	64	36	0.926	63.91260	64.92127	0.00654	6.09663	5.64548	60
28	65	37		64.91472	65.92338	0.00964	8.97681	0.00000	0
Energy gain per 100 nuclear absorption reactions (MeV)								860.18137	5976
Average energy gain per nucleus in first generation (MeV)								8.60181	
Average energy gain per nucleon in first generation (MeV)								0.14394	

The experimental values of atomic mass derive from the Audi and Wapstra[24] compilation available from the National Nuclear Data Center. If we add the mass of one neutron (1.008664923 amu) to the nuclear mass we have the value reported in the **Mass+n** column of the table. If we subtract the mass of the A+1 isotope given in the next row of the table then this represents a **Mass Gain/Loss** as shown in the seventh column. This represents an excitation energy

[23] P. Möller, J. R. Nix, and K. L. Kratz, ***Nuclear Properties for Astrophysical Applications***, Atomic Data Nuclear Data Tables **66 (1997)** 131, Los Alamos National Laboratories Report LA-UR-94-3898.

[24] G.Audi and A.H.Wapstra, ***The 1995 update to the atomic mass evaluation,*** **Nuclear Physics A595 vol. 4** p.409-480, December 25, 1995.

in the nucleus as shown in the next column. Multiplying the per nucleus gain by the isotopic abundance yields the net gain in energy for the group of 100 atoms. The final column notes the total number of nucleons in the subgroup. Summing the entire first generation neutron absorption excess energy gives us 860 MeV, or 8.6 MeV per nucleus. This is an average of 0.14 MeV per nucleon. Miley has suggested a net increase in binding energy of 0.1 MeV per nucleon, a value consistent with the present conclusion. This activation energy must show up as thermal energy in the cell. No evidence for thermal neutron capture gamma radiation has been reported. I have only shown the effect of a first generation neutron absorption process. Obviously, if we are to explain the existence of isotopes with mass numbers up to about 210 we are required to go through many generations of absorption and including beta decay processes. This is an unnecessary complication for this note. Suffice it to say that we could expect average energy production comparable to that shown here for each of the higher mass numbers.

To place all of the preceding in the proper context, it appears that a new class of nuclear reactions has been observed in electrolysis cells in which neutrons are created in an as yet unexplained manner and are in turn captured by the adjoining metallic lattice nuclei to form a heavier isotope element. Repeated captures may result in beta decay of the nucleus into a new higher atomic number element. As long as the cell continues operation, a process of elemental transmutation progresses towards heavier elements. A logical extension of this process could result in the nucleus itself becoming unstable to fission reactions which in turn could produce daughter fragments and subsequent release of fission energy. There is nothing in the process which restricts the neutron capture process to that of the metallic lattice. Wherever the neutron trajectory takes it, there is also a high probability of capture, in the electrolyte itself and the cell hardware and materials. The neutron is simply of sufficiently low energy to be absorbed very efficiently by the cell material nuclei. The facts are that these cells run hot and do not produce external radiation signatures of gamma, x-ray, and neutron , thus, there must be other mechanisms available to the nucleus to shed excess energy. Lattice vibration through phonon absorption has been proposed as one mechanism. The key to understanding this class of experiment appears to be that we are not dealing with a set of reactions which is required to overcome the Coulomb repulsion potential barrier. **Thus this is not a hot fusion experiment!** It has been shown that deuterium and tritium are not needed to produce the fusion reactions. Expensive palladium is not needed either. Other candidate electrode materials have been identified and successfully employed. If we turn to citations in the literature regarding biological transmutation evidence, there are many possible target nuclei. Apparently all that is really needed is the appropriate geometry and confinement of protons and electrons in spaces which are small relative to atomic dimensions to allow the creation of neutrons. There is also the suggestion that a source of energy is necessary to make the neutron creation energetically possible. We get the energy back with a return on investment in the capture process.

The capture of a thermal neutron by a nucleus may be the basis for the LENR and is not insignificant as compared with other energy forms:

- 6.8 MeV/nucleon in fusion characteristic of four hydrogen fusing to form one helium,
- 0.8 MeV/nucleon in the fission of one ^{235}U nucleus,
- 0.14 MeV/nucleon in a typical LENR neutron capture,
- 0.07 eV/nucleon in the energy of combustion in an high explosive (1500 cal/gm).

The LENR represents a logical transition in the energy comparison between chemical and nuclear energy and offers an interesting spectrum of possibilities through continuing research:

- Energy production in modest cell sizes from available metals and other materials,
- Reduction or elimination of radioactivity from high level nuclear wastes through transmutation of the isotope,
- Creation of rare metals from more common ones in the age-old dream of the alchemist,
- The opportunity to expand our physical knowledge in some really new physics.

It is a sad set of circumstances which has placed this issue in such a bad light. Clearly, there are many reasons why the original Pons and Fleischmann experiments were severely criticized, some for good reasons and some, unfortunately, for reasons of self interest and ignorance. Today with power and energy shortages sweeping across the nation and no clear solution to increased energy availability in a market dominated by non-renewable fossil energy sources, we need to look beyond the short term interest and develop a long term energy strategy which recognizes the potential of the LENR to help mitigate some of these problems. In truth, it may be possible with the proper research and development, to move the LENR to the forefront of our energy program to provide power itself and to eliminate the deterrence of nuclear waste to the expansion of the nuclear power industry. Besides that, it may allow us once more to pursue a line of physics in the laboratory which is affordable to all.