

POSSIBILITY OF DEUTERON DISINTEGRATION IN CONDENSED MATTER, A REVIEW

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1/16/2021

“Discovery consists of seeing what everyone has seen,
and thinking what no one has thought.”
Albert Szent-Gyorgi, 1937 Nobel Laureate in Physiology/ Medicine

“If we all worked on the assumption that what is accepted as true is really true,
There would be little hope of advance.”
Orville Wright

"I may disagree with what you say but will defend to the death your right to say it."
Voltaire, French writer, philosopher and historian

“La vérité est en marche, et rien ne l’arrêtera.”
Emile Zola

“Rien ne peut arrêter une idée don’t l’heure est venue.”
Victor Hugo

“We wish to pursue the truth, no matter where it leads. But to find the truth, we need imagination and
skepticism, both. We will not be afraid to speculate, but we will be careful to distinguish speculation from
fact.”

“Absence of evidence is not evidence of absence.”
Carl Sagan, Astronomer, ‘Cosmos’

“The miracle is not how well the bear waltzes,
but that it can waltz at all.”
PT Barnum

“There is only one way to avoid criticism: do nothing, say nothing, and be nothing.”
Aristotle. Greek philosopher

“I’ve missed more than 9,000 shots in my career.
I’ve lost almost 300 games.
Twenty six times, I’ve been trusted to take the game winning shot and missed.
I’ve failed over and over and over again in my life.
And that is why I succeed.”
Michael Jordan, USA Basketball Champion

“It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.”
Mark Twain

“The most difficult subjects can be explained to the most slow-witted man if he has not formed any idea of
them already; but the simplest thing cannot be made clear to the most intelligent man if he is firmly
persuaded that he knows already, without a shadow of a doubt, what is laid before him.”
Leo Tolstoy

“Consensus is not Unanimity.”
“Academic politics are particularly vicious because the stakes are so low.”

INTRODUCTION

From the 1870 book written by Jules Verne, “The Mysterious Island”:

“And what will they burn instead of coal?” “Water”, replied Harding. “Water!” cried Pencroft, “Water as fuel for steamers and engines!” “Water to heat water!” “Yes, but water decomposed into its primitive elements”, replied Cyrus Harding, “and decomposed doubtless, by electricity, which will then have become a powerful and manageable force, for all great discoveries, by some inexplicable laws, appear to agree and become complete at the same time. Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Someday the coal rooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous calorific power. There is, therefore, nothing to fear. As long as the Earth is inhabited it will supply the wants of its inhabitants, and there will be no want of either light or heat as long as the productions of the vegetable, mineral or animal kingdoms do not fail us. I believe, then, that when the deposits of coal are exhausted, we shall heat and warm ourselves with water. Water will be the coal of the future.”

Immediately after the reporting of Low Energy Nuclear Reactions in a D/Pd electrolytic cell in 1989 [1, 2], the absence of neutrons emissions from the neutron branch of the DD reaction suggested the possibility that other processes may be at-hand. Identifying already observed laboratory observations in particle accelerators research other than fusion, deuteron polarization through the Oppenheimer-Phillips process [3] was suggested by Ragheb et. al. as a possible explanation of the reported heat release [4, 5, 6]. Its possible occurrence in nature in the context of the Oklo Natural Reactors Phenomenon was next discussed in 1992 by Ragheb et. al. [7]. The proposed conventional nuclear science theory endures over time, does not invoke new unknown processes, and provides a possible explanation of some recent experimental results.

The suggestion of the Oppenheimer-Phillips Process [4, 5, 6] implied the possibility of neutron-induced transmutations and evolved into the designation of the reported observations, as more knowledge emerged, from Low Energy Nuclear Reactions (LENRs), to Condensed Matter Nuclear Science (CMNS) with an associated Journal of Condensed Matter Nuclear Science (Jcmns). The new field of CMNS is not considered as anomalous anymore. The initial identification of the process by Ragheb et. al. [4, 5 6] of “Condensed Matter” has survived into the new terminology: “Condensed Matter Nuclear Science” (CMNS). The investigations forked into two primary emphases: one using hydrogen in association with nickel and the other remaining with the initial deuterium and palladium components.

As nuclear reactions typically release energies in the MeV (10^6 eV) range, and the Deuterium to Hydrogen D/H ratio is 160 ppm (160×10^{-6}), in the Earth’s oceans, one can surmise that the product (10^6 eV \times 160×10^{-6} = 160 eV) could partially explain some of the

energy release observations reported using H in lieu of D as associated with the inevitable presence of D in the used H. As chemical reactions typically release energies in the 10 eV range (e. g. the ionization energy of hydrogen being 13.6 eV), this is a factor of about $160 / 10 = 16$ in the level of a possible energy release.

The process of deuteron disintegration from the perspective of the Oppenheimer-Phillips Process is hereby reviewed as a possible explanation for some of the reported observations.

Since 1989 the CMNS investigative efforts have so-far been elusive and did not produce a viable technological product. They may remain as scientific curiosities or perhaps some hoped-for dreams. Although the experimental efforts are admittedly difficult to reproduce, this type of exploration of frontier science by future engineers, scientists, students, academics as well as members of the public at large, is thought by its proponents to be conducive to future discovery, innovation, and invention. Because it challenges the existing paradigms, frontier science is understandably met with initial resistance by the mainstream scientific thinking. If CMNS involves chemical reactions, with energies in the eV range, inducing nuclear reactions in the MeV range, the harnessing of this potential would provide humanity with an abundant source of energy. So far, the achieved power is in the few Watts range, whereas useful consumer products are needed in the kW range for consideration as viable energy sources.

However, according to Steve Jobs (1955-2011):

“Here is to the crazy ones, the misfits, the rebels, the troublemakers, the round pegs in the square holes ... the ones who see things differently – they are not fond of rules ... You can quote them, disagree with them, glorify or vilify them, but the only thing you cannot do is ignore them because they change things ... they push the human race forward, and while some may see them as the crazy ones, we see genius, because the ones who are crazy enough to think that they can change the world, are the ones who do.”

Albert Einstein said that his theories were not finished, suggesting that science should always be in development. Some future bright mind readers just might lead the way to develop the conflicting theories and experimental observations into some beneficial future technology. Many hopeful sincere attempts in frontier fields have so far eluded success, reproducibility and technological applications. However, frontier scientists are found on the extreme edge or cusp of new understanding and knowledge and offer the freshest thinking from open minds chancing upon breakthrough discoveries in a fortuitous fashion.

According to Nobel Prize laureate in Physics (1973), Prof. Brian Josephson: “Since when has the majority of scientists in a field been right about something revolutionary (e.g. continental drift, the non-junk character of 'junk DNA', something incidentally predicted by intelligent design scientists)?” “The turkeys do not vote for Christmas.”

Inventors Thomas Edison and Nikola Tesla and even Galileo Galilei may have been considered at some point in time as frontier scientists. Conventional science is greatly important and valuable and its accomplishments are astounding and it continues to impress. A popular adage exists that science advances only at the funeral of one established scientist after another, as old paradigms fade away and are supplemented or replaced with new ones.

Usually new theories add elegance and complexity to the existing ones: Special and General Relativity Theories supplementing Newtonian Physics and Quantum Mechanics enriching Classical Mechanics, are examples. Plasma physics is enriching the universe's gravitational long-distance action foundation. Magnetic fields form from currents flows. For currents to flow, potential differences must exist. Electromagnetic interactions and Maxwell's equations are increasingly accounted-for in cosmic interaction theories. Some courageous physicists are exploring Tachyons; which are particles that possibly move at faster than the speed of light.

Both conventional and frontier science have a rightful and legitimate place at the table where knowledge is sought and found for the greater benefit of all humanity. The reader must be aware of the gap existing between the experimental knowledge and the theoretical knowledge in some fields. As aptly described by the Nobel Prize Laureate Hannes Olof Gösta Alfvén, Swedish electrical engineer, plasma physicist and winner of the 1970 Nobel Prize in Physics for his work on Magneto Hydro Dynamics (MHD), in the context of the complexity of thermonuclear research:

“Since thermonuclear research started with Zeta, Tokamaks, Stellarators - not to forget the Perhapsastron - plasma theories have absorbed a large part of the energies of the best physicists of our time. The progress which has been achieved is much less than was originally expected. The reason may be that from the point of view of the traditional theoretical physicist, a plasma looks immensely complicated. We may express this by saying that when, by an immense numbers of vectors and tensors and integral equations, theoreticians have prescribed what a plasma must do, the plasma, like a naughty child, refuses to obey.

The reason is either that the plasma is so silly that it does not understand the sophisticated mathematics, or it is that the plasma is so clever that it finds other ways of behaving, ways which the theoreticians were not clever enough to anticipate. Perhaps the noise generation is one of the nasty tricks the plasma uses in its IQ competition with the theoretical physicists.”

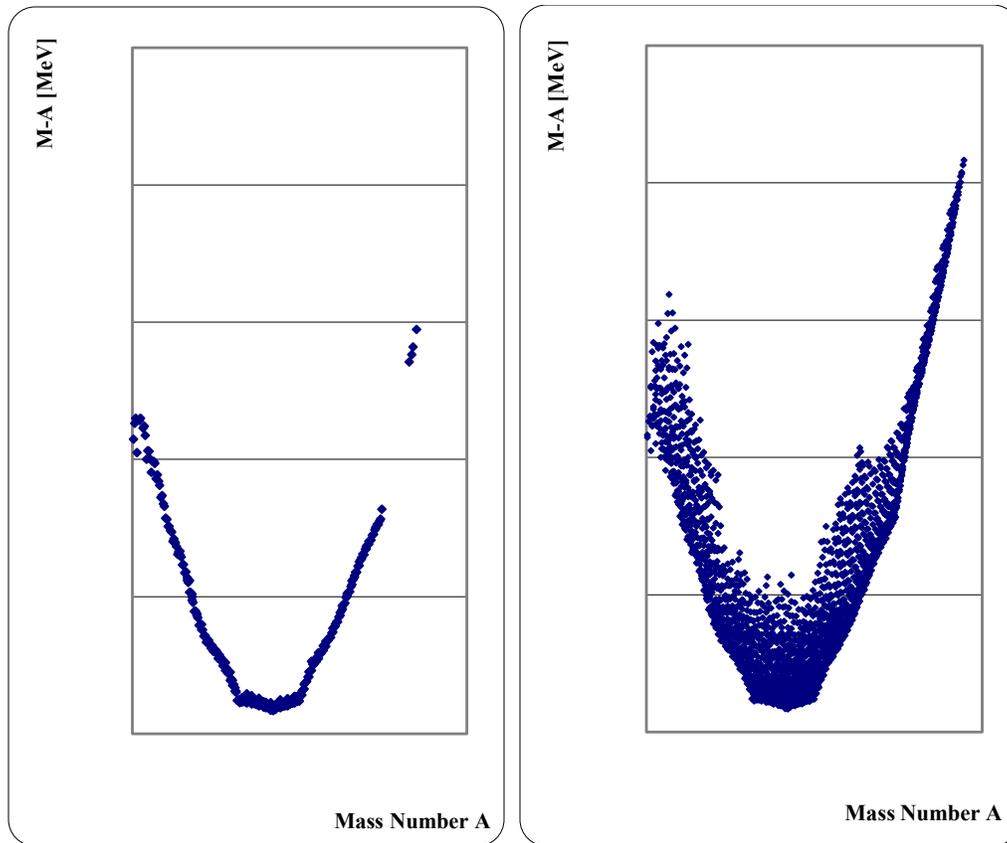


Figure 1. The mass defect diagram for the naturally-occurring (left) and the artificially-created isotopes (right) shows local minima as well as a major minimum around nickel and iron corresponding to nuclear shell structures.

We particularly emphasize the possibility of deuteron disintegration in condensed matter through photonuclear and wave polarization reactions known as the Oppenheimer Phillips process [3, 4] and the possibility of nucleo-synthesis that could originate outside stellar environments such as in the natural reactors in the Oklo Natural Reactors Phenomenon [5].

DEUTERON REACTIONS [3]

Deuteron disintegration is part of conventional nuclear science and is a recognized laboratory-observed effect in accelerator work. As reported in the 1966 Friedlander, Kennedy and Miller text on Nuclear and Radiochemistry [9] on “Deuteron Reactions”:

“It was found early in the study of nuclear reactions that (d, p) reactions occur *at deuteron energies well below the Coulomb barrier* (emphasis added) of the target nucleus and that the cross sections are considerably larger than those for the corresponding (d, n) reactions, *particularly for heavy nuclei* (emphasis added). These two observations are completely at odds with what would be expected from the compound-nucleus

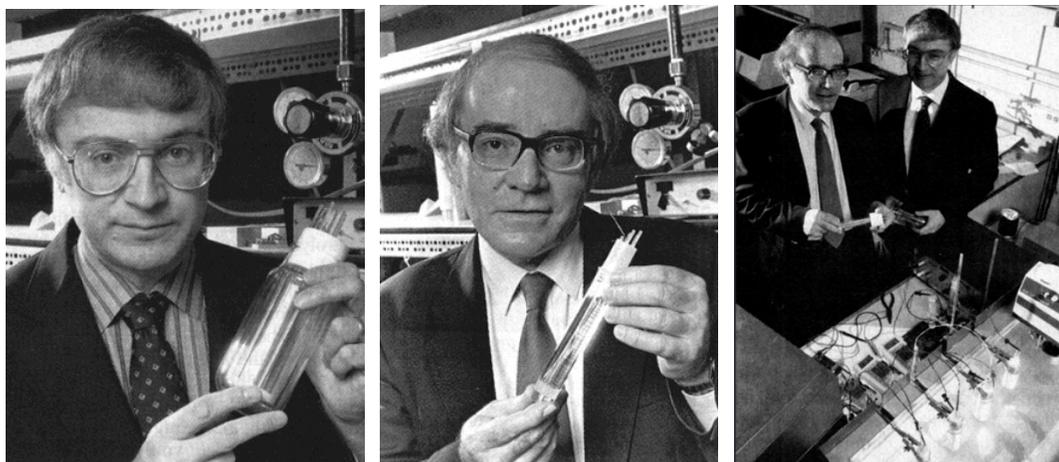
model: there should be essentially no reactions at energies below the Coulomb barrier, and neutron emission should predominate over proton emission from the few compound nuclei that may be formed, particularly with elements of high atomic number. This apparent anomaly has been explained by Oppenheimer and Phillips [3] as being the result of polarization of the deuteron by the Coulomb field of the nucleus. As the deuteron approaches the nucleus, its “neutron end” is thought to be turned toward the nucleus, the “proton end” being repelled by the Coulomb force. Because of the relatively large neutron-proton distance in the deuteron (several times 10^{-13} cm) the neutron reaches the surface of the nucleus while the proton is still outside most of the Coulomb barrier. Since the binding energy of the deuteron is only 2.23 MeV, the action of the nuclear forces on the neutron tends to break up the deuteron, leaving the proton outside the potential barrier. The process just described is generally called an Oppenheimer-Phillips (or O-P) process. An analogous mechanism appears to be responsible for the low energy (He^3 , p) reaction. An interesting feature of the O-P process is that the emergent protons have a spread of energies which includes values in excess of the incident deuteron energy, so that in a fraction of the events the excitations of the compound nucleus is that which would result from the capture of a neutron of negative kinetic energy.

With increasing deuteron energy, reactions other than the O-P process become possible; but because of the large size and low binding energy of the deuteron there seems to be no energy range in which deuteron-induced reactions can be described completely, or even largely, by the simple compound-nucleus picture. At high energies (>100 MeV) the dominant process becomes deuteron stripping, in which either the proton or neutron is tripped off by collision with a nucleus and the other nucleon continues essentially in the original direction of the deuteron with its share of the deuteron momentum [49]. The inverse reaction, the pickup process, is also observed: a fast proton picks up a neutron while making a glancing collision with a nucleus and leaves as a high-energy deuteron in the forward direction.

In addition to stripping, there are also compound-nucleus reactions with deuterons in the medium-energy range; the consequences are similar to those already discussed for medium-energy reactions with protons and α particles. The excitation functions, though, will often look quite different from those with protons and alphas because of the stripping reactions that are also occurring.”

HISTORICAL PERSPECTIVE

Deuteron disintegration could provide a source of neutrons leading to transmutations that would drive the surrounding elements to regions of higher stability as closed nuclear shells or nuclei with the magic numbers. Reports of LENRs were reported in 1989 by Pons and Fleishmann and Jones [1. 2] but were not consistently reproduced or replicated in laboratory experiments.



Preliminary note

Electrochemically induced nuclear fusion of deuterium

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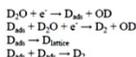
Stanley Pons

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(Received 13 March 1989; in revised form 22 March 1989)

INTRODUCTION

The strange behaviour of electrogenerated hydrogen dissolved in palladium has been studied for well over 100 years, and latterly these studies have been extended to deuterium and tritium [1]. For discharge of deuterium from alkaline solutions of heavy water we have to consider the reaction steps



(i)
(ii)
(iii)
(iv)

Figure 2. Stanley Pons, Chairperson, University of Utah Chemistry Department, USA and Martin Fleischmann FRS (Fellow of the Royal Society), University of Southampton, UK showing their respective electrolytic cells experiments using Deuterium and Palladium. Pons and Fleishman announcement on electrolytic experiments, March 23, 1989.

Fleishman and Pons from the University of Utah, as well as Steven Jones from Brigham Young University (BYU) are credited of widely reporting their results in 1989, giving all the needed data to try to reproduce worldwide their experiments. In fairness, Fleischmann and Pons were explicit that what they had found was an “unknown nuclear reaction,” and they only speculated that it might be fusion.

Upon realizing that the emphasis in the USA is on improving the design of existing systems rather than accepting innovative new technologies, Pons and Fleishman left the USA in 1992 to the south of France where the Technova Company, a subsidiary of the Toyota car company, funded a new laboratory: IMRA, to support their research.

The claim that the Pons and Fleischmann reports “could never be confirmed” appears to be actually preposterous. Pons and Fleischmann did make mistakes, but their central report on “anomalous heat” was never found to be wrong, and many others found it, once the conditions became better understood.

Pons and Fleischmann were looking to test the assumptions of plasma physics as applied to the solid state, where the interactions of particles may be far more complex than in a gas. They expected to find nothing because they thought the approximations were good enough, but, as true scientists, they had decided to look. Their experiment melted down, releasing more energy than they could explain with conventional chemistry, even though

they were world-class electrochemists. They waited 5 years to announce their results. Others rushed to confirm similar results without adequate information and Pons and Fleischmann themselves did not fully understand some aspects of their work.



Figure 3. Steven Jones from Brigham Young University (BYU).

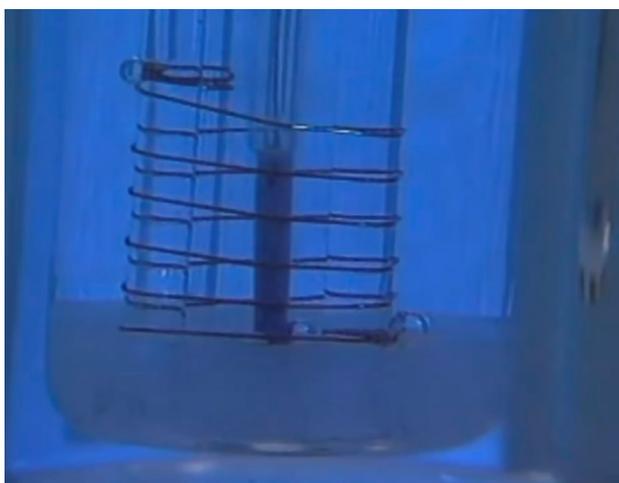


Figure 4. Pons and Fleishman electrolytic D/Pd cells. Stanley Pons and Martin Fleischmann at the University of Utah claimed to measure a production of heat that could only be explained by a nuclear process. Steven Jones at Brigham Young University did not observe heat but claimed to observe neutron emission that would also indicate a nuclear process

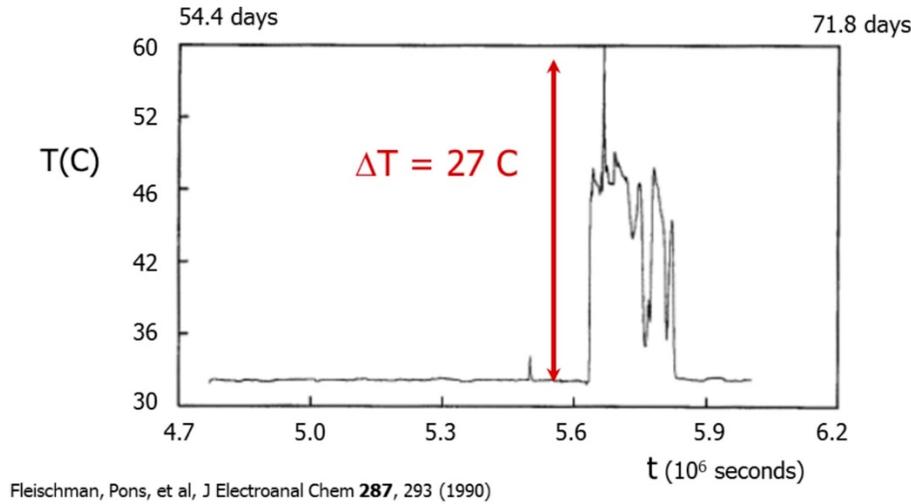


Figure 5. Temperature burst in Fleishman and Pons experiment.

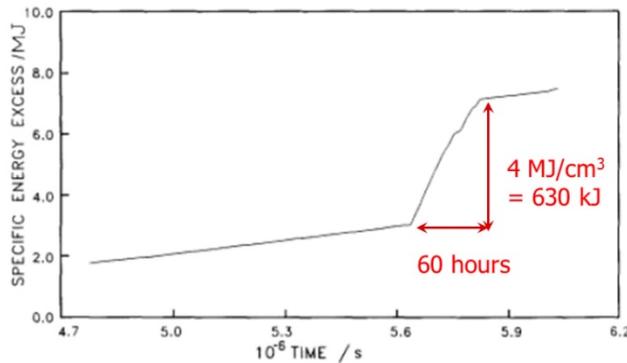


Figure 6. Energy gain in a Fleishman and Pons 1990 experiment. Power produced:

$$P = \frac{630kJ}{60hr} = \frac{630 \times 10^3 J}{60 \times 60 \times 60 sec} = 2.9Watts$$
 . The detonation of 0.157 cm^3 of the Pd cathode volume in TNT chemical explosive would yield just 0.0012 MJ. Source: Peter Hagelstein, MIT.

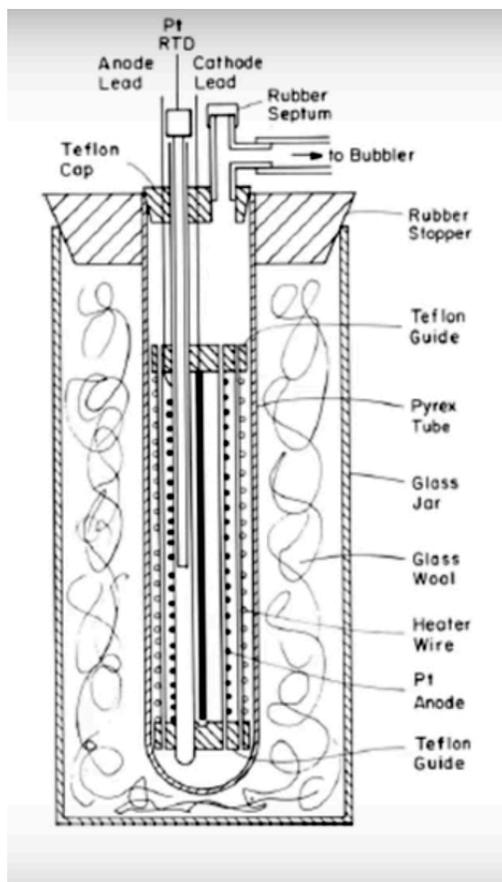


Figure 7. Details of a D/Pd electrolytic cell at MIT that could not replicate/confirm the Pons and Fleishman results.



Figure 8. Media frenzy on the Newsweek and Time magazines front covers.

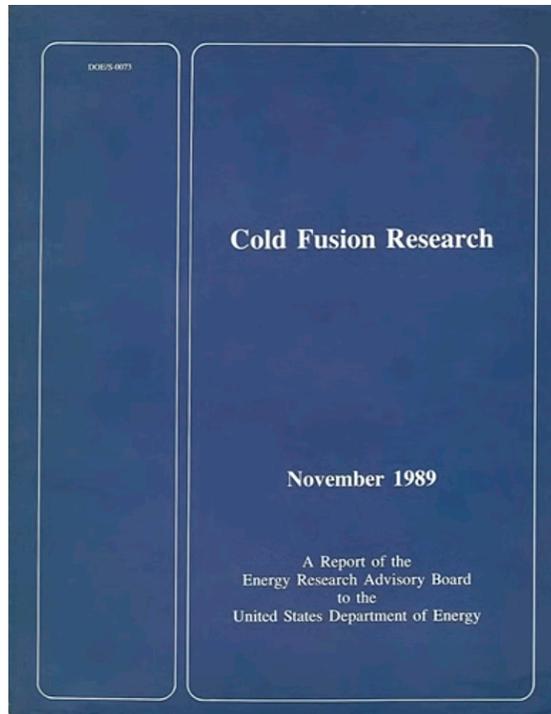


Figure 9. Energy Research Advisory Board (ERAB) Report, November 1989, denied research funding of LENRs research: “Nuclear fusion at room temperature, of the type discussed in this report, would be contrary to all understanding gained of nuclear reactions in the last half century; it would require the invention of an entirely new nuclear process.” The report discussed state-of-the-art contemporary fusion-physics processes, including Gamow quantum-mechanical nuclear Coulomb barrier tunneling. One single mention of deuteron disintegration was: “The Oppenheimer-Phillips process involving the Coulomb break-up of the deuteron has sometimes been invoked in this regard. However, this process is not effective at low energies in the D+D system.” [42].

The process evolved to be referred to as Condensed Matter Nuclear Science (CMNS) with hydrogen and nickel substituting deuterium and palladium as primary feed reactants. Other elements such as Ti were also considered. It must be observed that hydrogen still incorporates deuterium on Earth with an atomic ratio of D / H of 160 ppm. This ratio differs in other cosmic environments. Some may also speculate that in the electrolysis process, hydrogen ions are formed with an abundance of electrons which could lead to the formation of deuterons as a composite particle of an electron and two protons, or a proton and a neutron. The formed deuterons may perhaps then take part in the observed processes.

Evidence is presented about possible deuteron disintegration occurring in natural nuclear reactors as part of the Oklo phenomenon leading to an anomalous value in the Oklo mass-spectroscopy measurements of the deuterium D to hydrogen H ratio (D/H) at the Saclay National Laboratory in France from the natural occurrence value of 160 ppm in ocean water to the mass-spectroscopic measured value of 127 ppm. An estimate of the deuteron disintegration constant strictly under the conditions of the Oklo phenomenon is estimated by Ragheb et. al. as $7.47 \times 10^{-14} \text{ sec}^{-1}$ [5].

We discuss the possibility of fissile breeding using deuteron disintegration, the maintenance of a subcritical source driven systems, and present deuteron disintegration as a possible source of heating in comets and in the Earth's mantle and outer core; complementary to the radioactive decay of Th^{232} , K^{40} , and the uranium isotopes U^{238} , U^{235} and U^{234} .

One may also think about the possible transmutation of fission products or the actinides resulting from nuclear fission into shorter half-lives or stable nuclides, reducing the fission waste disposal issue.

The suggested terrestrial nucleo-synthesis process amounts to an increase in the pseudo nuclear entropy process, decreasing the D/H ratio in condensed matter, concentrating the occurrence of condensed matter around the local minima corresponding to the closed nuclear shells at the magic numbers, and at the major minimum corresponding to the most stable elements such as nickel and iron, in the mass defect versus mass number curve for both the natural and artificial nuclides.

The proposed mechanism may have been observed as different manifestations of Low Energy Nuclear Reactions (LENRs) earlier-on reported by Fleishmann and Pons and by Jones et. al. [1, 2] and later pursued by numerous authors. It is currently referred to as Condensed Matter Nuclear Science (CMNS).

MAGIC NUMBERS NUCLIDES

Neutron capture from deuteron disintegration could encourage the migration of the surrounding nuclides to regions of high stability and high abundance with respect to the neighboring nuclides.

These are characteristics for nuclei for which the magic numbers for N or Z are 2, 8, 20, 28, 50, 82, and 126. The magic nuclei are more tightly bound and require more energy to be excited than the non-magic nuclei. These correspond to closed shells in the structure of the nucleus in the same way that we encounter closed electronic shells in the structure of the atom.

The frequency of the stable isotones, which are nuclides with an equal number of neutrons is shown as a function of the neutron number $N = A - Z$. Higher frequencies of occurrences correspond to the magic numbers.

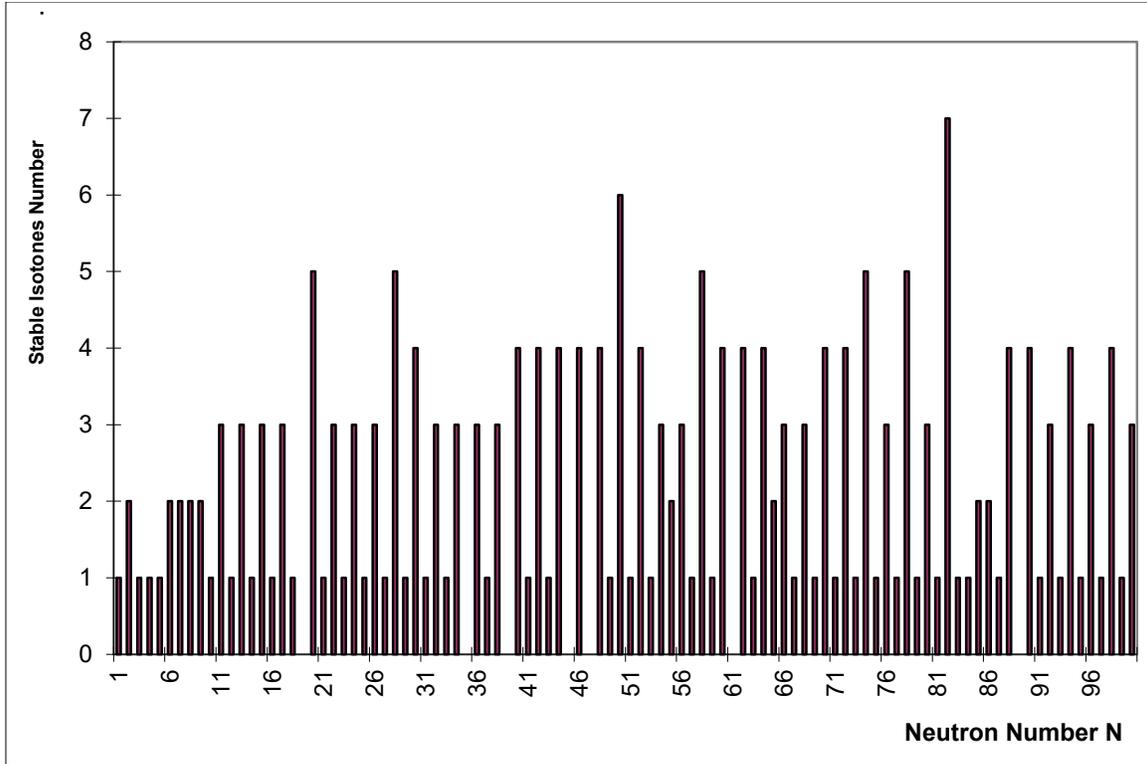


Figure 10. The frequency of the stable isotones as a function of the neutron number N. Higher frequencies correspond to the magic numbers N = 20, 28, 50 and 82.

UNIQUE CHARACTERISTICS OF THE DEUTERON

The deuteron ${}_1\text{D}^2$ possesses unique characteristics compared to the other stable nuclei in nature:

1. It is the only known existing two-particle nuclear bound system.
2. It has the lowest Binding Energy (BE) among all other nuclei. Table 1 compares the BE per nucleon and the total binding energy of the deuteron to the other nuclei.
3. Deuterons do not possess any excited states that are stable with respect to decomposition.
4. In the deuteron nucleus, the constitutive neutron and the proton spend about one half of the time outside the range of the nuclear forces. Using the expression for the nuclear radius:

$$R = 1.25A^{\frac{1}{3}}[fm] = 1.25 \times 10^{-13} A^{\frac{1}{3}}[cm] \quad (1)$$

where: A is the mass number of the nucleus,
 1 fm = 1 Fermi = 10^{-13} cm

the radius of the deuteron will be:

$$R = 1.25 \times 2^{\frac{1}{3}} = 1.57[fm] = 1.57 \times 10^{-13}[cm]$$

- compared with the separation distance between the neutron and the proton at 4 fm.
5. The charge distribution of the deuteron nucleus is very unsymmetrical.
 6. The separation between the center of mass and the center of charge in the deuteron is the most extreme among other nuclei.

These characteristics suggest that even though the deuteron is stable with respect to natural radioactive decay, it is a relatively loose particle that may break up if it existed under conditions that will further enhance the instabilities in its nuclear structure to the point of disintegration.

Table 1. Binding Energy per nucleon (BE / A) and total Binding Energy (BE) of typical nuclides.

Nuclide	BE/A [MeV/nucleon]	BE [MeV]
${}^2_1\text{D}$	1.11	2.22
${}^3_1\text{T}$	2.83	8.48
${}^3_2\text{He}$	2.57	7.72
${}^4_2\text{He}$	7.08	28.30
${}^6_3\text{Li}$	5.33	32.00
${}^7_3\text{Li}$	5.60	39.20
${}^9_4\text{Be}$	6.47	58.19
Average per nucleon	8.50	-

ORIGIN OF DEUTERIUM

It is believed that virtually all the deuterium in the universe was created in nuclear reactions in the first 2 minutes after the postulated Big Bang. This left the universe with a Deuterium to Hydrogen ratio (D/H) of 27 parts per million (ppm). This matches both theoretical calculations and measurements conducted by the Wilkinson Microwave Anisotropy Probe (WMAP) satellite launched by NASA to measure the afterglow remnant of the Big Bang.

Through the process of nucleo-synthesis, the D/H ratio, according to various models, should have fallen into the range of 10-15 ppm. Measurements in the 1970s by the Copernicus satellite reveals that the ratio D/H varies from one site to another in the Milky Way galaxy. This contradicted the view that hydrogen is well mixed within the galaxy and therefore the same D/H ratio should be expected throughout the galaxy.



Figure 11 The Dust Cloud star AE Aurigae contains deuterium. NASA Photograph.

In 2006, observations with NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) looked for the signature of deuterium in ultraviolet light coming from various locations in the galaxy. Attention was directed to dusty and relatively undisturbed regions by searching for low levels of gaseous silicon and iron. The reasoning was that these elements condensed into solid dust grains that would have deuterium attached to them. The measurements estimated that the D/H ratio in these dusty locations was 5 ppm. Other observations found D/H ratio levels at 23 ppm in environments where the dust was likely to vaporize at the vicinity of hot stars and supernovae. The current belief is that the galaxy's overall D/H ratio is the higher value of 23 ppm, with the lower value of 5 ppm thought to be only as an illusion caused by the deuterium hiding on silicon and iron dust grains.

The higher observed ratio of D/H at 23 ppm compared with the theoretically expected D/H ratio of 10-15 percent resulting from stellar nucleosynthesis, suggests that an unexpectedly large 85 percent of the hydrogen gas in our galaxy has never been inside a star. An explanation of the higher ratio suggests that the galaxy has absorbed much more pristine gas that is unaltered by the stars than previously thought. This could have occurred by the Milky Way galaxy absorbing other smaller galaxies which processed their gas at a slower rate than the Milky Way galaxy.

DEUTERIUM IN METEORITES

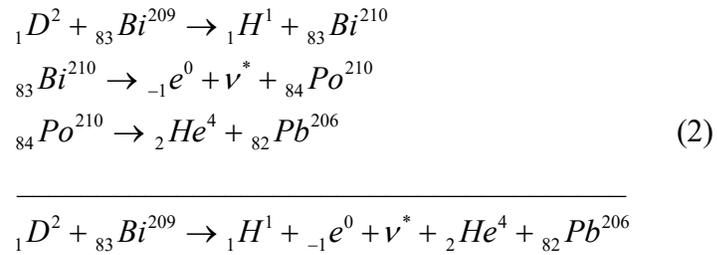
Some meteorites as comets contain organic molecules that date back to the birth of the planets about 4.56 billion years ago. It is observed that these organic molecules in interplanetary dust are unusually rich in deuterium and the isotope N^{15} . The conclusion is that they are just as primitive as the solar system. The D/H ratio in the comets Halley, Hyakutake and Hale-Bopp averaged 320 ppm or $320 / 23 = 13.9$ times that in the solar system.

In the atmospheres of the gaseous planets Jupiter and Saturn the D/H ratio is about 20 ppm. The Earth's sea water has a D/H ratio of 160 ppm; an enrichment of $160 / 23 = 6.96$ times relative to its value in the solar nebula.

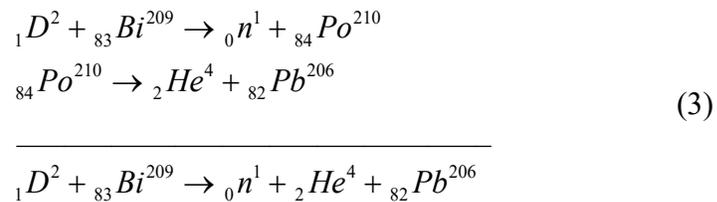
An interesting observation is that the D/H ratio on Earth at 160 ppm has lost ½ its deuterium compared with the one in the comets (320 ppm) which are surmised to be a source of water through their impacts on Earth.

DEUTERIUM WAVE POLARIZATION, THE OPPENHEIMER-PHILLIPS PROCESS

Early on in the study of nuclear reactions, it was observed that (D, p) reactions occur at deuteron energies well below the Coulomb barrier of a target nucleus, particularly for the heavy elements. Moreover, the cross sections are considerably larger than those for the corresponding (D, n) reactions. These reactions were observed in the accelerator bombardment of the Bi²⁰⁹ isotope, which occurs with a 100 percent natural abundance, with deuterons resulting in the production of polonium²¹⁰ as an alpha emitter, possibly used in Space Nuclear Auxiliary Power Systems (SNAPs), or as a neutron source trigger for early nuclear implosion devices through the (α, Be^9)n reaction. Po²¹⁰ eventually decays into the stable isotope lead²⁰⁶:



This reaction appeared favored, emitting protons, to what was thought to be the expected, yet unobserved, basic reaction, emitting neutrons through compound nucleus formation:



These two observations were at odd with what would be expected from the compound nucleus model for nuclear reactions, which suggests that there should not be reactions below the Coulomb barrier and that neutron emission should predominate over proton emission from the compound nucleus formed.

Robert Oppenheimer and Phillips explained this apparent anomaly based on the peculiar properties of the deuteron. The deuteron is a loosely bound nuclear structure with a binding energy of only 2.23 MeV. This can be calculated as:

$$BE = [Z.M(p) + N.M(n) - M^*] \times 931.5 \tag{4}$$

or:

$$BE = [Z.M(H) + N.M(n) - M] \times 931.5 \quad (5)$$

M(p) = mass of proton

M(n) = mass of neutron

where: M(H) = neutral atom mass of hydrogen

M' = mass of bare nucleus

M = mass of neutral nuclide

Thus for the deuteron, the nuclear binding energy is:

$$BE = [M(H) + M(n) - M(D)] \times 931.5 = 2.2246 \text{ MeV}$$

M(D) = 2.01410179 amu

where: M(n) = 1.00866497 amu

M(H) = 1.00782504 amu

This is actually determined experimentally from the threshold for the photodisintegration reaction of the deuteron into a proton and a neutron:



and combined with the mass spectrographic data for the masses of H and D to determine the neutron mass, since no accurate method for a direct measurement of the neutron mass is known.

The deuteron binding energy of 2.2246 MeV is evidently low compared with that of other nuclei: 8.48 MeV for the triton ${}_1T^3$; 7.72 MeV for ${}_2He^3$, 28.3 MeV for the alpha particle ${}_2He^4$, 32 MeV for ${}_3Li^6$, 39.2 MeV for ${}_3Li^7$, and about 8.5 MeV for the average nucleon in a nucleus.

The absence of excited states of the deuteron, its low binding energy, and its large size (the neutron and the proton spend about one half the time outside the range of the nuclear force) result from the weakness of the nuclear force when viewed in the context of its small range. Moreover, the charge distribution of the deuteron is very unsymmetrical. Its center of mass and its center of charge do not coincide as they do in the case of the alpha particle. A large separation of about 4×10^{-13} cm exists between the constituents' proton and neutron, which actually spend most of their time outside the range of their attractive mutual force.

Robert Oppenheimer and Phillips [3] explained the preponderance of proton emission over the expected neutron emission on the basis of a quantum-mechanical model of the deuteron as a wave function with a proton and a neutron components. As the deuteron wave function approaches the Coulomb barrier of a nucleus, a polarization effect occurs repelling away the positively-charged proton component, but not affecting the neutral neutron component. As the deuteron gets closer to the nucleus, the neutron

component of the wave function can be captured by the nucleus, leaving the proton component unaffected. The net effect appears as a neutron capture process where the neutron is passed on from the deuteron to the nucleus, with the proton left free.

The process only invokes polarization and does not involve any tunneling process through the Coulomb barrier.

VOLKOFF AND BETHE CALCULATIONS OF THE OPPENHEIMER-PHILLIPS PENETRABILITIES OF THE NUCLEUS POTENTIAL BARRIER

Volkoff [25].calculated the ratio of the Oppenheimer-Phillips penetrability to the Gamow-Condon-Gurney penetrability of the nucleus potential barrier which invokes tunneling through the Coulomb barrier. He considered this ratio for different nuclei of charge Z as a function of the deuteron energy in MeV. His most interesting observation was that the ratio increases for lower deuteron energies, as well as for higher values of Z .

Hans Bethe [26] also calculated the same ratio for various nuclear charges Z as a function of the deuteron energy. He also observed that his calculations predict a higher ratio at lower deuteron energies, even below the deuteron binding energy.

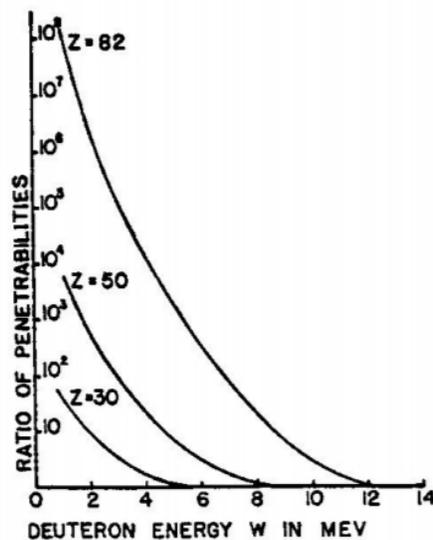


Figure 12. The ratio of the Oppenheimer-Phillips to the Gamow penetrability of the nucleus potential barrier for different values of the atomic number Z as a function of the deuteron energy W , as reported by Volkoff [25].

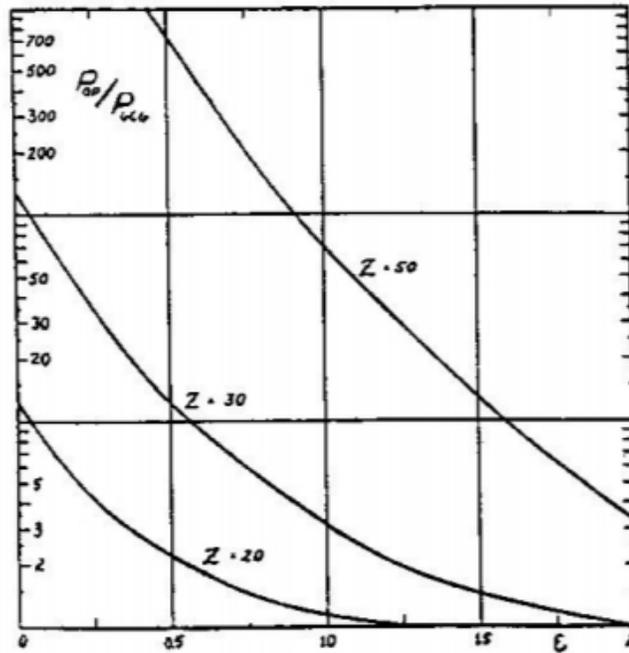


Figure 13. The ratio of the Oppenheimer-Phillips to the Gamow penetrability of the nucleus potential barrier for different values of the atomic number Z as a function of the ratio of deuteron kinetic energy to its binding energy as reported by Hans Bethe [26].

The works of Volkoff and Hans Bethe suggests that at low deuteron energy, the Oppenheimer-Phillips process will predominate over classical tunneling of the Coulomb barrier. In addition, it increases as the nuclear charge increases, suggesting its higher preponderance in the heavy elements compared with the light elements.

NATURAL SOURCES OF GAMMA RAYS

Neutrons can originate from natural environmental causes, such as cosmic rays showers. They can also originate from energetic gamma rays from natural sources such as Tl^{208} , a member of the thorium²³² natural decay chain, which emits gamma rays at an energy above the nuclear binding energies thresholds for ${}^2\text{D}$ as well as ${}^9\text{Be}$. In fact, the maximum photon energy from Tl^{208} is 2.614 MeV above the deuteron binding energy threshold of 2.26 MeV, and it occurs with an intensity of 100 percent.

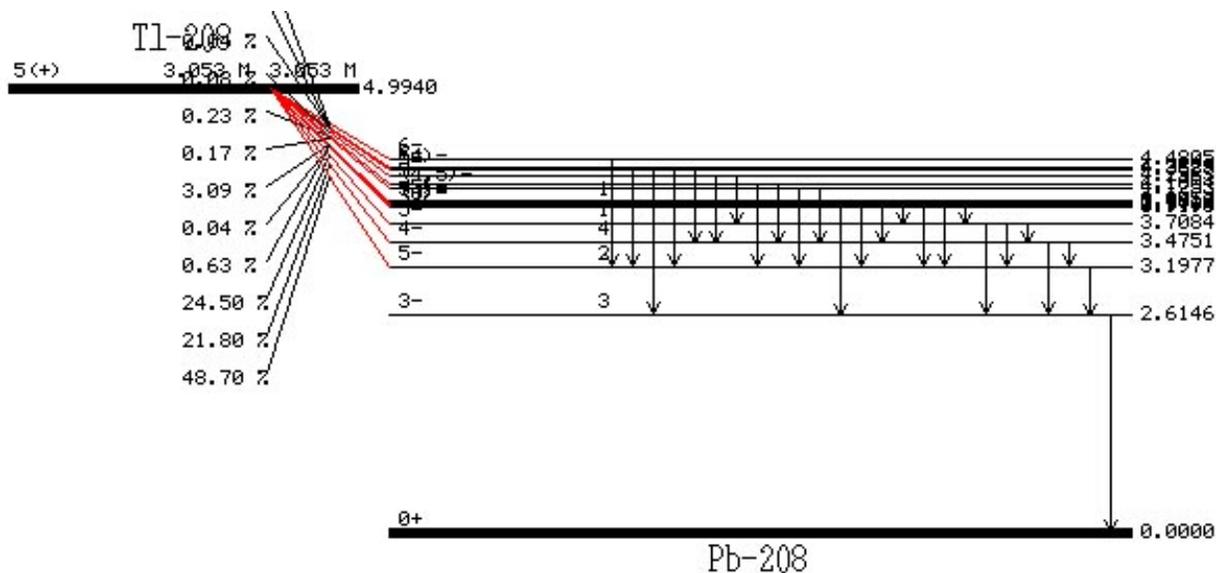


Figure 14. Gamma rays emissions from the ^{208}Tl isotope.

Table 2. Gamma ray energies and their relative intensities in ^{208}Tl .

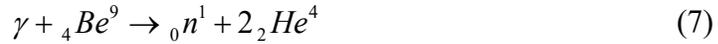
Isotope	Gamma ray photons energy [keV]	Relative Intensity Percent*
^{208}Tl	211.400	0.180
	233.360	0.310
	252.610	0.700
	277.358	6.360
	277.720	-
	485.950	0.050
	510.770	22.800
	583.191	85.200
	587.700	0.040
	650.100	0.036
	705.200	0.0220
	722.040	0.203
	748.700	0.043
	763.130	1.830
	821.200	0.040
	860.564	12.530
	883.300	0.031
	927.600	0.132
	982.700	0.205
	1,004.000	0.005
	1,093.900	0.400
	1,125.700	0.005

	1,160.800	0.011
	1,185.200	0.017
	1,282.800	0.052
	1,381.100	0.007
	1,647.500	0.002
	1,744.000	0.002
	2,614.533	100.000

* For absolute intensity multiply by 0.9916

PHOTO NUCLEAR AND DEUTERIUM BERYLLIUM DISINTEGRATION

One can consider the interaction by a few high energy gamma photons from common naturally occurring gamma ray sources such as ${}_{81}\text{Th}^{208}$ through photo-nuclear (γ, n) reactions as a cause of deuteron disintegration. For instance one can consider the interaction of energetic gamma photons with Be^9 , which possesses a relatively loose last neutron, through the reaction:



A photon carrying 1.67 MeV or more energy can photo-disintegrate the nucleus of Be^9 which is composed of 100 percent of natural beryllium, its only stable isotope.

Antimony¹²⁴ with a half-life of 60.2 days, is mixed with beryllium to make a laboratory neutron source or a startup neutron source. It emits negative beta particles and 1.69 MeV gamma rays as well as a 0.602 MeV and nine fainter emissions from 0.645 to 2.090 MeV, yielding stable Tellurium¹²⁴. Gamma rays from the Antimony¹²⁴ knock off intermediate neutrons from the beryllium⁹ with an average kinetic energy of 24 keV. The other product is two alpha particles [19. 20].

Other isotopes have higher thresholds for photo-neutron production, as high as 18.72 MeV, for Carbon¹² [21].

In fact, the binding energy of the last neutron in the ${}_4\text{Be}^9$ nucleus is just 1.57 MeV. This can be calculated as follows:

$$\begin{aligned} BE({}_4\text{Be}^9) &= \{[2M({}_2\text{He}^4) + M({}_0n^1)] - M({}_4\text{Be}^9)\} \times 931.5 \\ &= 1.5734 \text{ MeV} \end{aligned}$$

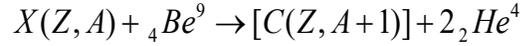
The threshold energy for this reaction, which is also the binding energy of the last neutron in the ${}_4\text{Be}^9$ nucleus is:

$$E_{th}^{4\text{Be}^9} = 1.666 \pm 0.002 \text{ MeV}$$

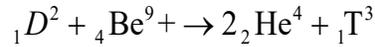
The emitted neutrons would then be absorbed in the other surrounding elements. The resulting helium could be the one observed in some Condensed Matter Nuclear Science (CMNS) reported experiments.

With the exception of deuterium and beryllium, the binding energy of the last neutron for other nuclei lies between 5 and 13 MeV.

If ${}^9_4\text{Be}$ is considered, we can write a neutron capture reaction:



If deuterium is considered, if say beryllium deuteride is used, the following reaction could occur:



which is a charged particle neutronless reaction that emits tritium as well as He^4 .

PHOTO NUCLEAR DEUTERON DISINTEGRATION

One can also consider the photo disintegration reaction of the deuteron:



A photon carrying 2.22 MeV or more energy can photo-disintegrate a nucleus of deuterium. James Chadwick and Maurice Goldhaber used this process to measure the neutron and proton mass difference [17]. This experiment proves that a neutron is not a bound state of a proton and an electron-as had been proposed by Ernest Rutherford [18].

The generated neutrons could activate some other elements in the sample, creating some radioactive species and causing transmutations.

As an example, in heavy water (D_2O) cooled and moderated reactors such as the Canadian Deuterium Uranium (CANDU) design, those neutrons are absorbed in deuterium itself leading to the production of tritium through the reaction:



The binding energy of the deuteron is known to be equal to:

$$E_{th}^{D^2} = 2.226 \pm 0.003 \text{ MeV}$$

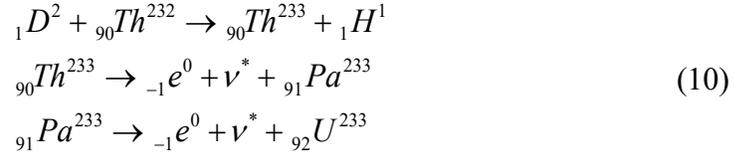
Gamma photons from ${}^{208}_{81}\text{Th}$ with an energy of 2.614 MeV would be capable of disintegrating the deuteron with its lower binding energy of 2.226 MeV without the need to invoke any other phenomena such as tunneling through the Coulomb barrier, nor for that matter electron shielding to surmount the barrier.

DEUTERON FISSILE BREEDING

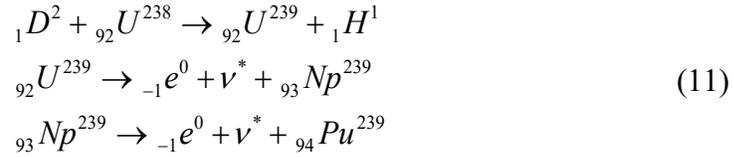
Through deuteron disintegration, it may be possible to consider the nuclear transmutations through neutron capture of the fertile isotopes into fissile ones. This would

not need the achievement of a critical configuration in a nuclear reactor or the use of particles accelerators as neutron sources.

The relevant nuclear reactions with the Th^{232} isotope would be:



The relevant nuclear reactions with the U^{238} isotope would be:



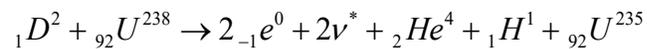
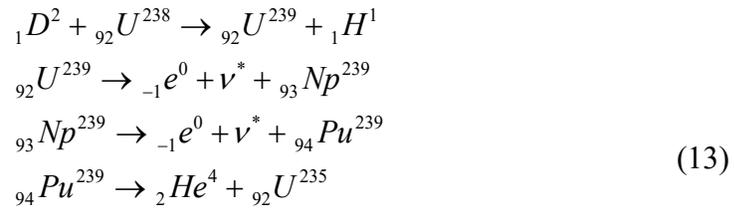
With the availability of further neutrons from deuterons, one can even foresee the possible fission of the bred isotopes, leading to the interesting situation of an equivalent fusion-fission hybrid without the need of achieving fissile isotopes critical masses.

DEUTERON DISINTEGRATION IN NATURAL REACTORS, THE OKLO PHENOMENON

Over the time span conditions of the Oklo phenomenon, the produced fissile isotope ${}_{94}\text{Pu}^{239}$ would have further decayed through the reaction:

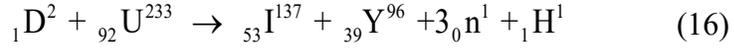
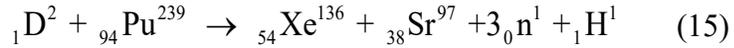
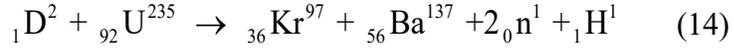


The overall reaction would then be:



Notice that the helium produced here would result from a radioactive decay process rather than a fusion process.

Deuteron disintegration can also lead to the fission of the produced fissile isotopes generating elements in the middle of the periodic table of the elements such as:



The presence of neutrons from these reactions could lead to the establishment of a source S driven subcritical system generating a neutron flux:

$$\begin{aligned} \phi &= S + kS + k^2S + k^3S + k^4S + \dots \\ &= S(1 + k + k^2 + k^3 + k^4 + \dots) \end{aligned} \quad (17)$$

where k is the multiplication factor.

For a subcritical system, k is less than unity and we can write:

$$\phi = \frac{S}{1-k}, \quad \forall k < 1 \quad (18)$$

This provides a plausible alternative explanation for the occurrence of the Oklo phenomenon as a subcritical rather than a critical system. This subcritical configuration would have allowed the reactors to operate over the actually observed long time period of thousands of year. A critical configuration would have depleted the fissile isotopes over an unobserved explosive supercritical short time period.

DEUTERON DISINTEGRATION IN VOLCANIC PROCESSES [42]

“Products of low-level cold fusion have been inferred to be produced by natural geologic processes. The ${}^3\text{He}:$ ${}^4\text{He}$ ratio is anomalously high in volatile emissions from deep-source volcanoes such as those in Hawaii, Iceland, and Yellowstone; anomalous T is also suggested by fragmentary data, and production of other radiogenic products such as ${}^{36}\text{Cl}$ have been predicted.”

Although the high ${}^3\text{He}$ values have previously been considered relics from early earth processes, presence of anomalous T or anomalous ${}^{36}\text{Cl}$ (beyond that due to nuclear devices atmospheric testing in the 1950s) would be definitive evidence of natural CMNS reactions deep within the earth. Implications would be major for geophysical problems such as heat-flow modelling, element-distribution with depth, and composition of the Earth's core [42].

EARLIER HYBRID FISSION-FUSION RESEARCH, GLOW DISCHARGE WITH DEUTERIUM AND URANIUM FOILS

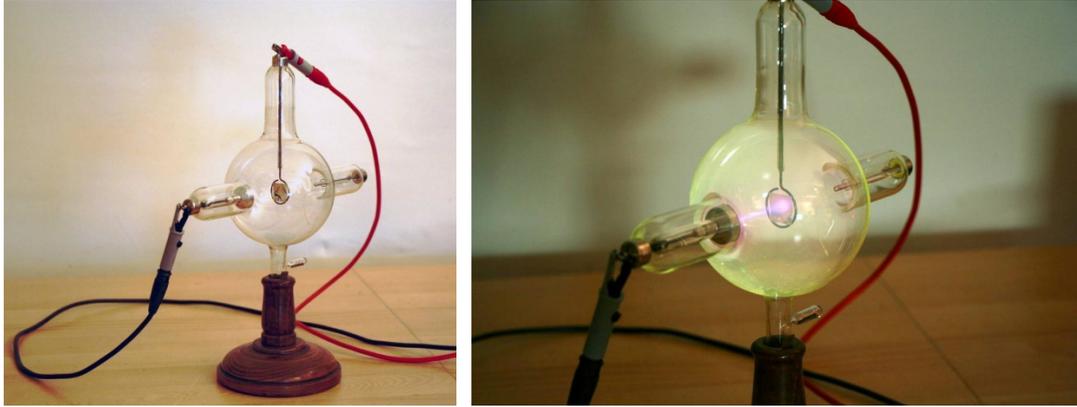


Figure 15. Deuterium gas filled Crookes glow discharge tube with uranium metal foils experiments in the 1920s.

In 1929, Walter Hermann Nernst (1864-1941), Nobel Laureate in Chemistry in 1920, remarked on experiments on hydrogen gas interaction with uranium metal in the *Zeitschrift* magazine:

“Hydrogen will dissolve into certain metals as if the metal was acting like a dry sponge absorbing water.”

Similar glow discharge experiments were earlier reported by Lord Raleigh.

If deuterium is dissolved in heavy metals such as uranium or palladium metal beyond a critical threshold concentration, an interaction between the deuterium and uranium and the metal was expected. If it is a form of deuteron disintegration, it may become an avenue of energy release from the heavy metals without the need to reach a critical mass of the fissile elements.

Glow-discharge experiments were conducted using Crookes tubes filled with deuterium gas and uranium foils. These were precursors to the Farnsworth Fussier experiments attempting the electrostatic fusion of deuterium in the 1960s.

Niels Bohr suggested that this approach could lead to the production of small nuclear devices instead of the critical mass approach, which would be more suitable for large devices.

GLOW DISCHARGE WITH DEUTERIUM GAS AND Pd FOILS

Karabut, Kucherov, and Savvatimova [30 -33] used a chamber with a Pd foil of 0.1-1 mm thickness in an atmosphere of D_2 at 3-10 Torr pressure. Thermistors measured the foil temperature and this served as a calorimeter. In the chamber were detectors for neutrons, gammas and charged particles as well as x-rays.

When running the experiment, excess heat, neutrons, gammas and charged particles were detected. These measurements were however not in the ratios expected from a fusion reaction. Postmortem examination of the foil revealed some increase in He^3 and an increase by factors of 4-100 in He^4 . All nuclear products, however, were at levels 3-4 orders of

magnitude lower than commensurate with excess heat. The authors regard the calorimetry results as promising. The abstract to one of their papers says:

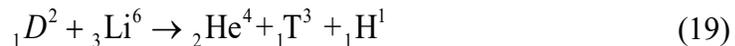
“New results for glow discharge in deuterium calorimetry are presented. In separate experiments a heat output five times exceeding the input electric power was observed. The result for the charged particle spectrum measurement is presented. Charged particles with energies up to 18 MeV and an average energy of 2—4 MeV were seen. Beams of gamma-rays with energies of about 200 keV and a characteristic x-ray radiation were registered. The summed energy of the registered products is three orders short of the values needed to explain the calorimetric results.”

Their conclusion raises questions about the possible existence of multiple processes:

“Many new questions arise with the latest results. The trigger mechanism of the nuclear reaction still remains unclear. As we already pointed out charged particles with a good portion of alphas are found in quantities 3–4 orders short of those needed to explain the excessive heat. We did not measure the electron flows in our work and this still leaves the possibility of K-electron capture with a radioactive isotope formation with a consequent beta decay with large energy release. A more plausible scenario is that the main mass of the charged particles does not leave the cathode.”

DEUTERON DISINTEGRATION FOR FUSILE BREEDING

In the same way that fissile breeding may be achievable through the process of deuteron disintegration, fusile breeding may be achievable using lithium through a tritium breeding reaction:



The generated proton could interact with deuterons leading to:



The proton could also interact with the produced tritium, further producing helium through the reaction:



ENHANCED RADIOACTIVITY AND MUON CATALYSED FUSION

For a while, no one thought that a nuclear property such as the half-lives of radioactive isotopes or the fusion rate can be altered by environmental factors.

Otto Reifenschweiler showed in 1994 that the activity of tritium absorbed in titanium particles could be reduced by 40 percent at temperatures in the range of 115-275 °C.

Muon catalyzed fusion was predicted in 1947, and there was an agreement between theory and experiments that showed that a small temperature change can considerably alter the fusion rate.

Catalysis of Nuclear Reactions by μ Mesons*

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Radiation Laboratory, University of California, Berkeley, California
(Received December 17, 1956)

IN the course of a recent experiment involving the stopping of negative K mesons in a 10-inch liquid hydrogen bubble chamber,¹ an interesting new reaction was observed to take place. The chamber is traversed by many more negative μ mesons than K mesons, so that in the last 75 000 photographs, approximately 2500 μ^- decays at rest have been observed. In the same pictures, several hundred π^- mesons have been observed to disappear at rest, presumably by one of the "Panofsky reactions."² For tracks longer than 10 cm, it is possible to distinguish a stopping μ meson from a stopping π meson by comparing its curved path (in a field of 11 000 gauss)



FIG. 1. Example of H-D reaction catalyzed by μ^- meson. The incident meson comes to rest, drifts as a neutral mesonic atom, is ejected with 5.4 Mev by the H-D reaction, comes to rest again after 1.7 cm, and decays.

between the last bubble of the primary track and the

Figure 16. Muon- Catalyzed fusion. H-D reaction catalyzed by μ^- meson.

HELIUM-PRODUCING REACTIONS WITH CARBON

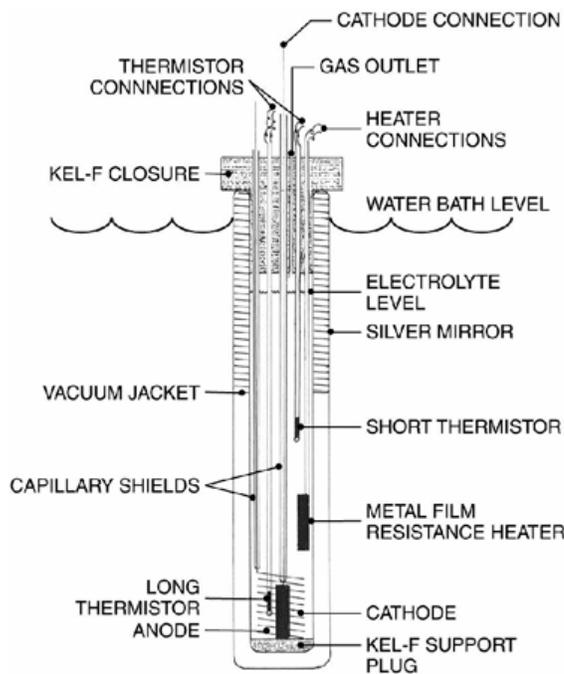


Figure 17. Silvered Dewar used in USA Navy's Space and Naval Warfare Systems Center, SPAWAR experiment.

The USA Navy's Space and Naval Warfare Systems Center SPAWAR at San Diego, California researchers reported to have experimentally observed low energy nuclear reactions in a presentation at the American Chemical Society's annual meeting on March 23, 2009 at Salt Lake City.

The results suggest a scientific detection of highly energetic neutrons from Condensed Matter Nuclear Science (CMNS). Normal hot fusion reactions, where hydrogen is fused into helium, occur at millions of degrees inside the sun and the stars. If room temperature fusion reactions could be realized commercially, it promises to produce abundant nuclear energy from deuterium extracted from seawater.

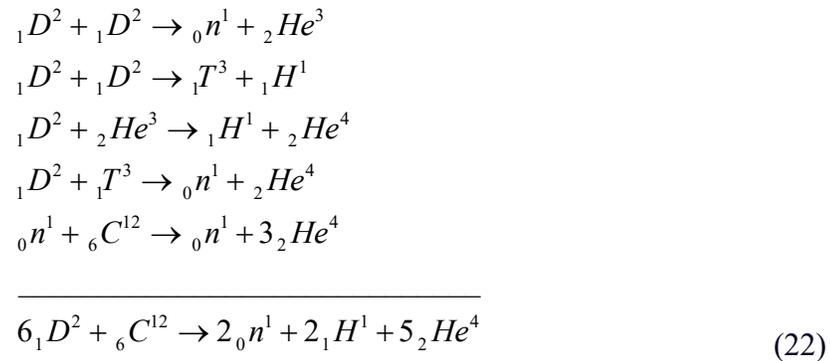
The advanced hypothesis is that when electrolysis is performed on deuterons, molecules are fused into helium, releasing a high energy neutron. While excess heat has been detected by the researchers, no group had yet been able to detect the missing neutrons.

The researchers suggest that the problem was instrumentation, which was not up to the task of detecting such small numbers of neutrons. To sense such small quantities, a special plastic detector called CR-39 used in neutron cancer dosimetry as well as eye-glass lenses was used. Using co-deposition with nickel and gold wire electrodes, which were inserted into a mixture of palladium chloride and deuterium, the detector was able to capture and track the high-energy neutrons.

Since the announcement by Fleischmann and Pons that the excess enthalpy generated in the negatively polarized Pd-D-D₂O system was attributable to nuclear reactions occurring inside the Pd lattice, there have been sporadic reports of tritium and He⁴ production; emission of energetic particles, gamma or x-rays, neutrons; as well as the transmutation of elements.

Using an electrode of gold or nickel, the team sent an electric current through a solution of palladium chloride mixed with deuterium, causing a reaction to occur within seconds. Using a special chamber made of CR-39 plastic, they were able to capture and track any high-energy particles that may have been emitted during reactions, including any neutrons emitted during the fusion of the deuterium nuclei.

The results of Pd–D co-deposition experiments conducted with the cathode in close contact with CR-39, a solid-state nuclear etch detector rich in carbon, solitary tracks due to individual energetic particles, and triple tracks were observed. Microscopic examination of the bottom of the triple track pit shows that the three lobes of the track are splitting apart from a central point. The presence of the three alpha particle tracks outgoing from a single point could be a diagnostic of the $^{12}\text{C}(n, n')3_2\text{He}^4$ carbon breakup reaction within the overall reaction:



and suggests that DT reactions that produce ≥ 9.6 MeV neutrons are occurring inside the Pd lattice. This would be the first report of the production of energetic neutrons in the Pd–D system.

To check whether these reactions are energetically possible, we calculate a positive overall Q-value of the reaction as:

$$\begin{aligned}
 Q &= \{[6M({}_1D^2) + M({}_6C^{12})] - [2M({}_1H^1) + 2M({}_0n^1) + 5M({}_2He^4)]\} \times 931.5 \\
 &= \{[6 \times 2.01410179 + 12.00000000] - [2 \times 1.00782504 + 2 \times 1.00866497 + 5 \times 4.00260330]\} \times 931.5 \\
 &= \{24.0846107 - [2.01565008 + 2.01732994 + 20.0130165]\} \times 931.5 \\
 &= \{24.0846107 - 24.04599652\} \times 931.5 \\
 &= 0.03861418 \times 931.5 \\
 &= 35.97 \text{ MeV}
 \end{aligned}$$

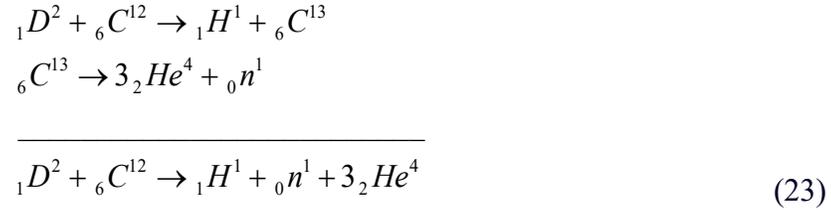
After two to three weeks, the team found a small number of "triple tracks" in the plastic; three 8-micrometre-wide pits radiating from a point. The team suggests such a pattern occurs when a high-energy neutron strikes a carbon atom inside the plastic and shatters it into three charged alpha particles that rip through the plastic leaving tracks. No such tracks were seen if the experiment was repeated using light water H_2O , rather than heavy water D_2O .

It is believed that these "triple tracks" are proof that the neutrons are active during the reaction. But there is still some uncertainty as to what is happening to cause the

neutrons to appear. The team believes, though, “that the neutrons originated in nuclear reactions, perhaps from the combining or fusing deuterium nuclei.”

High-energy neutrons are unlikely to be produced by a normal chemical reaction, so they may be created during the fusion of deuterium and tritium atoms tightly packed in the palladium framework at the cathode. The tritium also being a product of the fusion of two deuterium atoms.

If the deuteron disintegration is considered as the underlying mechanism, then the following simpler and more plausible overall two step reaction can be advanced as controlling the reported process:

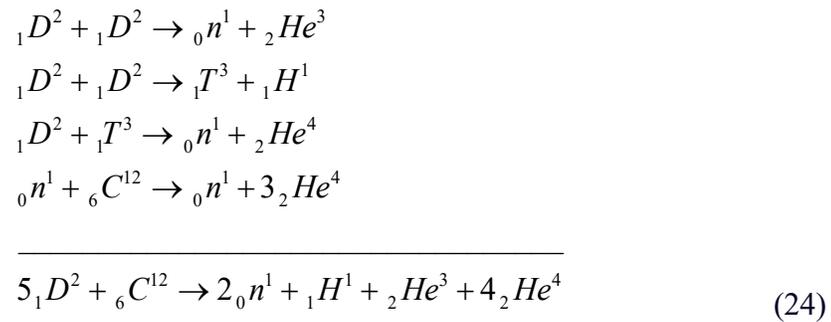


In that suggested explanation, the isotope ${}_6C^{13}$ acts as a catalyst in the process disintegrating into a neutron and the observed three alpha particles.

To check whether these reactions are energetically possible, we calculate the Q-value of the reaction as:

$$\begin{aligned}
 Q &= \{[M({}_1D^2) + M({}_6C^{12})] - [M({}_1H^1) + M({}_0n^1) + 3M({}_2He^4)]\} \times 931.5 \\
 &= \{[2.01410179 + 12.00000000] - [1.00782504 + 1.00866497 + 3 \times 4.00260330]\} \times 931.5 \\
 &= \{14.01410179 - 14.02429991\} \times 931.5 \\
 &= -0.01019812 \times 931.5 \\
 &= -9.4995 \text{ MeV}
 \end{aligned}$$

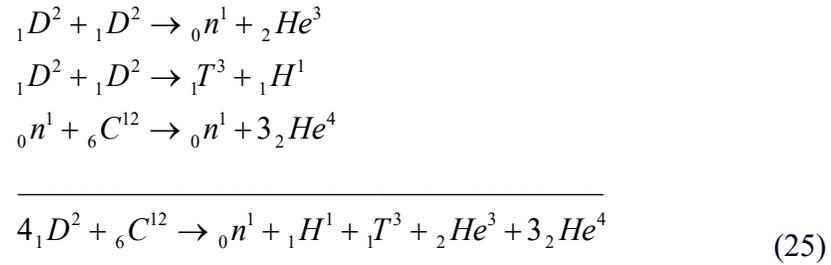
This is an endothermic reaction requiring an energy input of 9.5 MeV to the deuteron, compared with the fusion reactions in Eqn. 22 which yield a positive Q value of 36 MeV; making it the more energetically possible reaction. It is clear that the net energy release requires the occurrence of the DT and DHe³ reactions. If we consider that the DHe³ reaction does not occur, then the overall reactions would be:



And the Q value of the reaction would be:

$$\begin{aligned}
Q &= \{[5M({}_1D^2) + M({}_6C^{12})] - [M({}_1H^1) + 2M({}_0n^1) + M({}_2He^3) + 4M({}_2He^4)]\} \times 931.5 \\
&= \{[5 \times 2.01410179 + 12.00000000] - [1.00782504 + 2 \times 1.00866497 + 3.01602930 + 4 \times 4.00260330]\} \times 931.5 \\
&= \{22.07050895 - [1.00782504 + 2.01732994 + 3.01602930 + 16.0104132]\} \times 931.5 \\
&= \{22.0846107 - 22.05159748\} \times 931.5 \\
&= 0.03301322 \times 931.5 \\
&= 30.75181443 \text{ MeV}
\end{aligned}$$

which is a lower, yet still positive value, leading to a net energy release. If we further disallow the DT reaction, we get the overall reaction:



and the Q value of the reaction would be:

$$\begin{aligned}
Q &= \{[4M({}_1D^2) + M({}_6C^{12})] - [M({}_1H^1) + M({}_0n^1) + M({}_1T^3) + M({}_2He^3) + 3M({}_2He^4)]\} \times 931.5 \\
&= \{[4 \times 2.01410179 + 12.00000000] - [1.00782504 + 1.00866497 + 3.01604900 + 3.01602930 + 3 \times 4.00260330]\} \times 931.5 \\
&= \{20.05640716 - [1.00782504 + 1.00866497 + 3.01604900 + 3.01602930 + 12.0078099]\} \times 931.5 \\
&= \{20.05640716 - 20.05637821\} \times 931.5 \\
&= 0.00002895 \times 931.5 \\
&= 0.026966925 \text{ MeV} \\
&= 26.97 \text{ keV}
\end{aligned}$$

Even though the Q value is positive, it is just about 27 keV. This establishes the important conclusion that to obtain significant energy release, the DT reaction must be allowed to proceed. This would offer a possible explanation of the lack of reproducibility of the energy release in such reported experiments. Significant energy releases are feasible if the experimental setup and conditions allow the occurrence of the DT reaction with its substantial energy release of 17.6 MeV and its fast neutron energy of 14.06 MeV that must cause further interactions and should not be allowed to escape from the system by providing it with elements with a large reaction cross sections to interact with, such as lithium or fissile and fissionable nuclei.

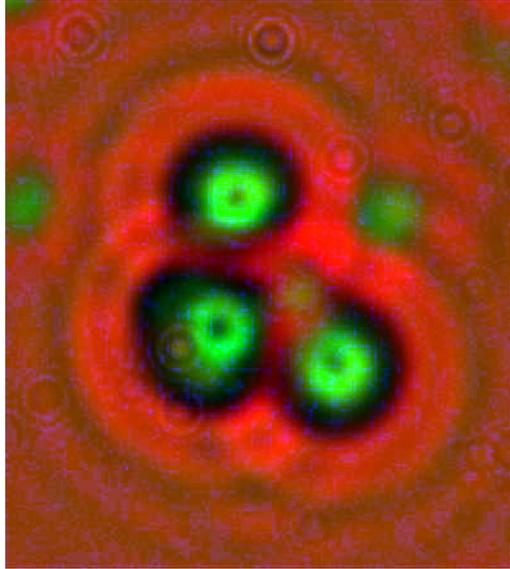


Figure 18. Triple tracks in CR-39 plastic solid state neutron detector.

OTHER TENTATIVE THEORETICAL AND EXPERIMENTAL EXPLANATIONS OF CONDENSED MATTER NUCLEAR SCIENCE (CMNS)

DEUTERIUM CLUSTERS FORMATION IN NANO-MATERIALS, PATTERSON CELLS STUDIES

In these experiments, the following triggering mechanisms are suggested for the reaction between Pd and Deuterium [22, 23, 24]:

1. Electrolysis, pulse or ramp,
2. Gas loading, pulse pressure. Smaller heat capacity. Higher temperature change as compared with an electrolysis system. Without the constraint of being limited by the boiling temperature of the fluid.
3. Glow Discharge (bombardment)
4. Low energy laser; ultrasound; electromagnetic radiation.

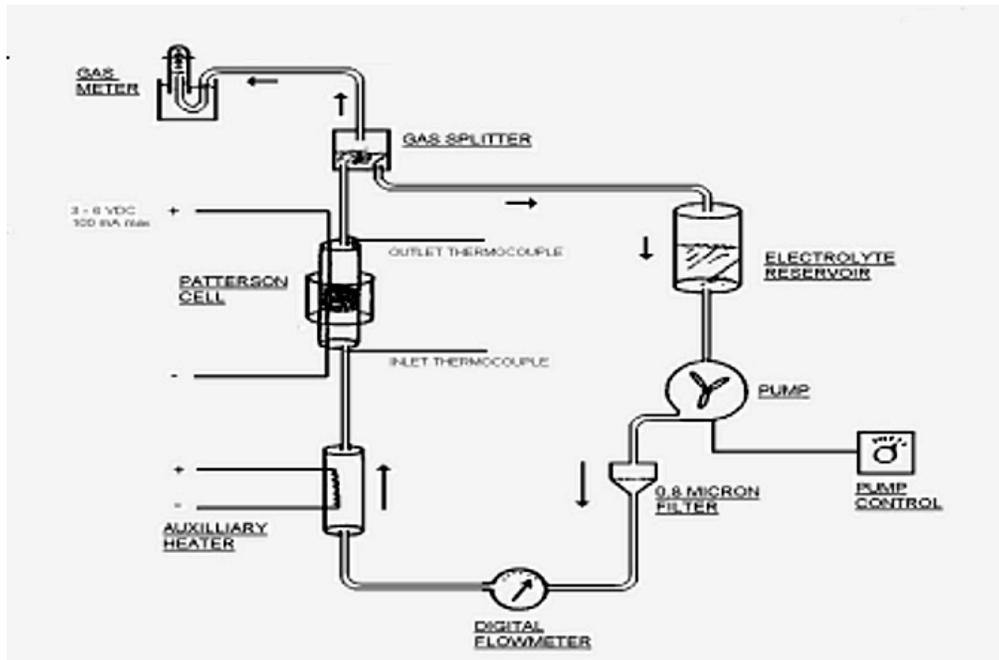


Figure 19. Process Flow of Patterson Cell electrolysis experiment [23].

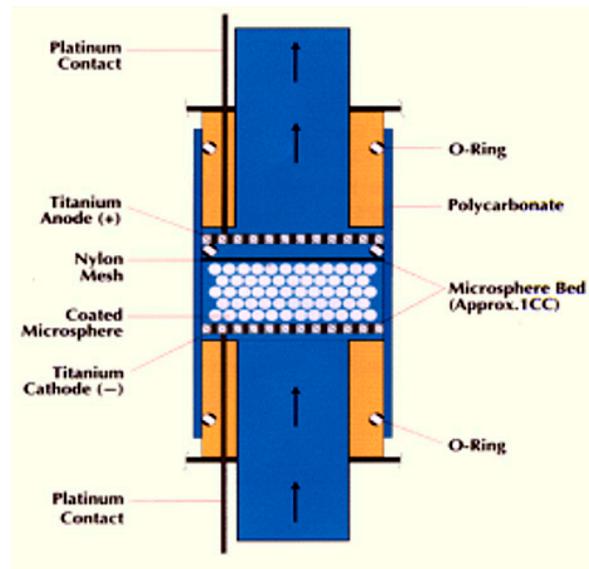


Figure 20. Patterson Power cell configuration [24].

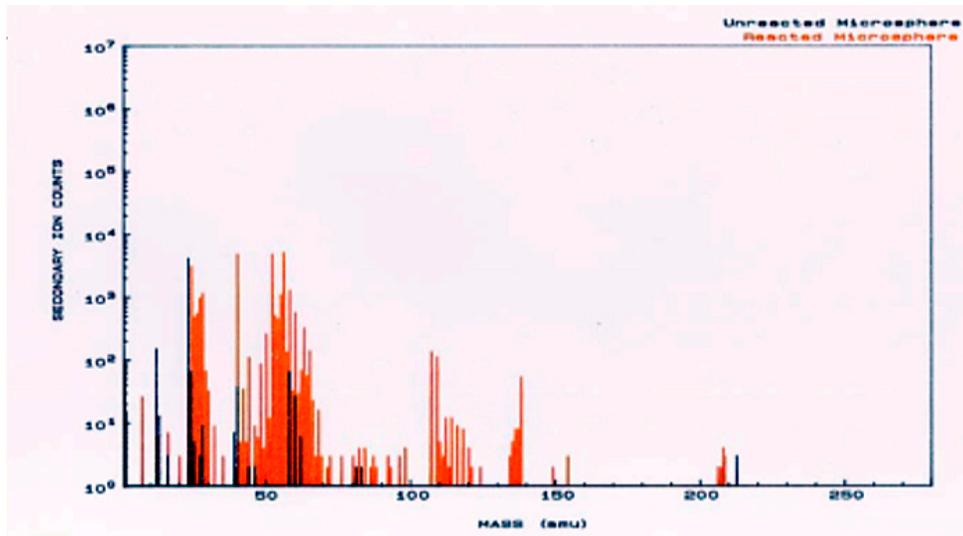


Figure 21. Mass Spectrum of a sample changes on untreated then reacted microspheres are attributed to isotopic shifts of isotopes before and after electrolysis, but are probably leaching from steel piping alloying elements. Results from SIMS and Neutron Activation Analysis (NAA). Secondary-Ion Mass Spectrometry (SIMS) is a technique used to analyze the composition of solid surfaces and thin films by sputtering the surface of the specimen with a focused primary ion beam and collecting and analyzing ejected secondary ions. [24].

Element	Concentration (ppm)	Error (ppm)	Detection Limit (DL) (ppm)
Ag	1.88	0.14	0.02
Al	40.66	2.75	1.60
Cu	< DL		24.62
V	< DL		0.19

Table 5.7(a). NAA result of microspheres from batch #prior to run #15.

Element	Concentration (ppm)	Error (ppm)	Detection Limit (ppm)
Ag	5.53	0.38	0.47
Al	39.17	3.24	4.21
Cu	141.54	26.79	79.10
V	1.02	0.15	0.32
Fe	1528.83	59.93	135.47
Cr	722.79	7.63	3.81
Co	18.23	0.29	0.21
Ni	1123.88	18.46	24.99

Table 5.7(b). NAA result of microspheres from batch #15.1.1 after run #15.

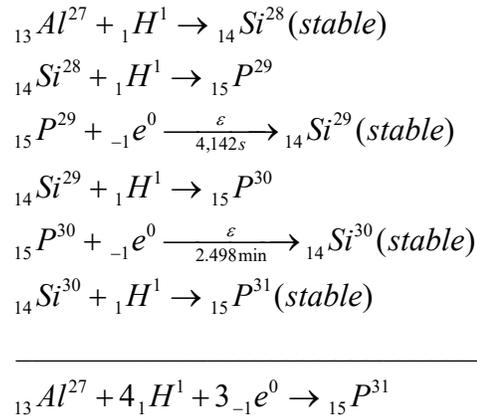
Figure 22. Neutron Activation Analysis (NAA) results before and after electrolysis runs of microspheres show isotopic shifts in eight selected elements [24]. Some of these possibly include impurities leached from alloying elements in the device's piping and components.

Table 3. Elemental composition of Stainless steel SS310 (UNS S31000) alloy.

Element	Percent
Carbon	0.25
Manganese	<2.00
Silicon	<1.50
Chromium	24.00-26.00
Nickel	19.00-22.00
Molybdenum	-
Phosphorus	<0.45
Nitrogen	-
Sulfur	<0.3
Selenium	-
Aluminum	-
Titanium	-
Niobium (Columbium) + Tantalum	-
Iron	Balance: 47.5-52.5

The presence of Cr and Ni can be probably attributed to leaching from steel alloying elements, rather than elemental transmutation products.

POSSIBLE TRANSFORMATION OF Al^{27} INTO Si AND P IN ASSOCIATION WITH H USE AS A REACTANT



Neither Si nor P appear in the activation analysis results, implying other processes are at work. However this may suggest that H interaction with Al in stellar atmospheres may explain the preponderance of the abundance of Si as a cosmological element.

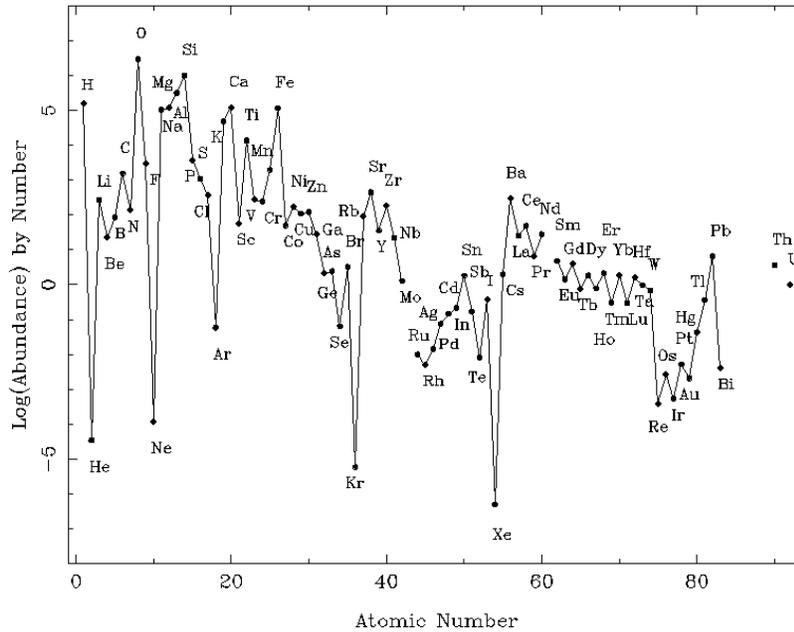
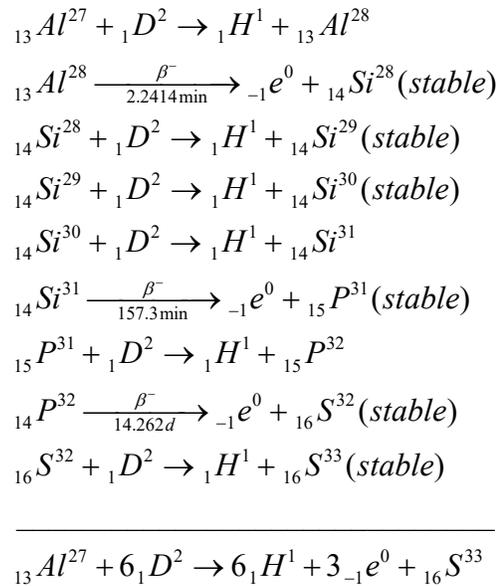


Figure 23. Crustal abundance of the elements. Si exceeds Al in abundance.

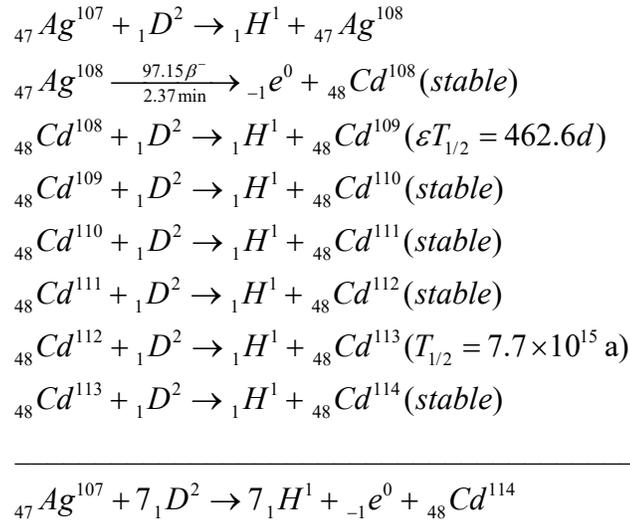
POSSIBLE TRANSFORMATION OF Al^{27} INTO S^{33} WITH D AS A REACTANT



Sulfur does not appear in the products nuclei, so it is not what is occurring in these experiments. Incidentally sulfur is associated with volcanic eruptions suggesting a possible Al to S transformation through the intermediary of D donating neutrons to the transformation.

POSSIBLE TRANSFORMATION OF Ag^{107} INTO Cd^{114} WITH A AS A REACTANT

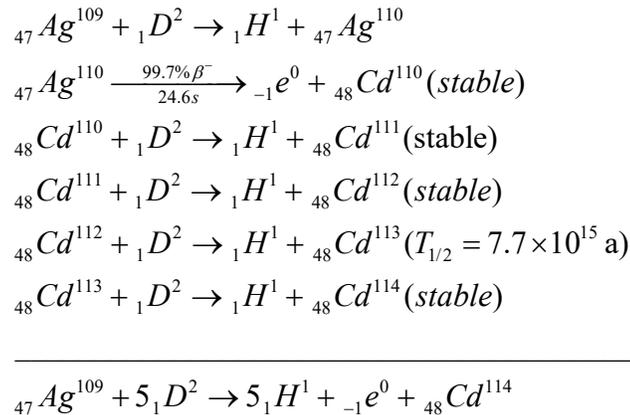
Considering the first naturally occurring isotope of Ag, Ag¹⁰⁷: (51.839 a/o):



Cadmium does not appear in the products nuclei, so it is not what is occurring in these experiments.

POSSIBLE TRANSFORMATION OF Ag¹⁰⁹ INTO Cd¹¹⁴ WITH D AS A REACTANT

Considering the second naturally occurring isotope of Ag, Ag¹⁰⁹: (48.161 a/o):



The chain joins the other Ag¹⁰⁷ chain at the Cd¹¹⁰ node leading to the same end product Cd; which also does not explain the experimental result.

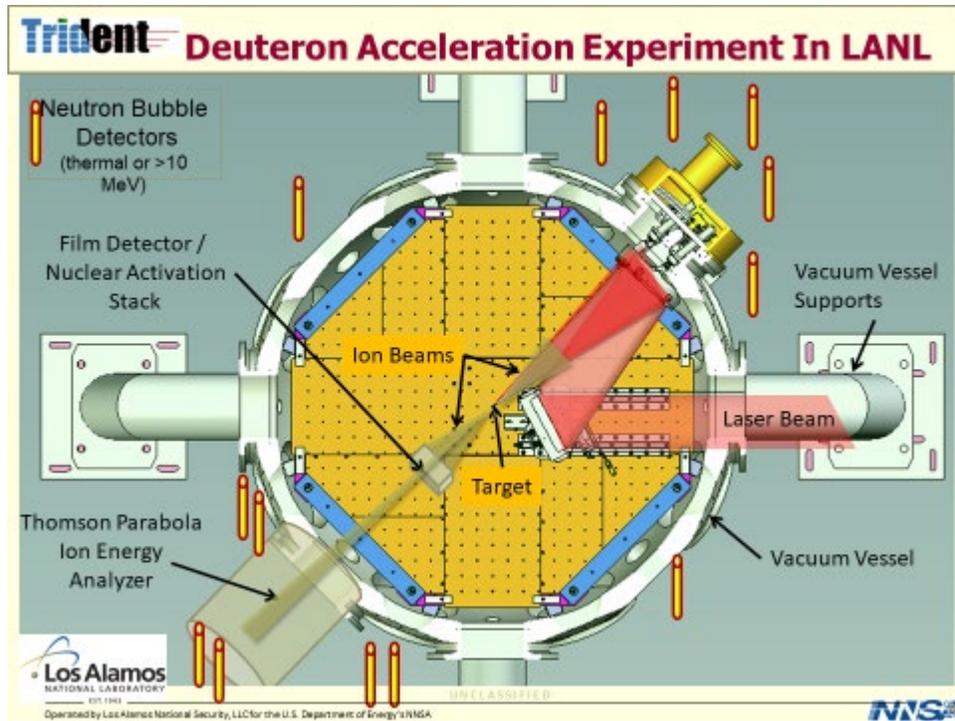


Figure 24. Trident Deuteron Acceleration Experiment at the Los Alamos National Laboratory (LANL) [24].

THE “STELLAR ATMOSPHERIC FUNCTION IN REGULATION EXPERIMENT” SAFIRE ELECTRICAL DISCHARGE PLASMA EXPERIMENT

The Safire experiment aims at exploring the properties of an electrical discharge plasma. SAFIRE is an acronym for “Stellar Atmospheric Function in Regulation Experiment”. The Safire Project is a set of laboratory-based experiments to “explore the role of electricity in stellar and planetary phenomena”, in particular, to independently test the Electric Sun theory. Based on a “Design of Experiments” approach, and using a SCADA control system, Safire focuses primarily on observation and experimentation, instead of theory and simulations [27].

An intriguing result was the observation of an evaporation of the Langmuir probes used in the measurement of the plasma parameters. This was associated with the observations of the appearance of isotopes which could be considered either as impurities or as transmutations pending further experiments. The experiment uses hydrogen, which inevitably contains deuterium offering a possible explanation for the occurrence of suspected transmutations.

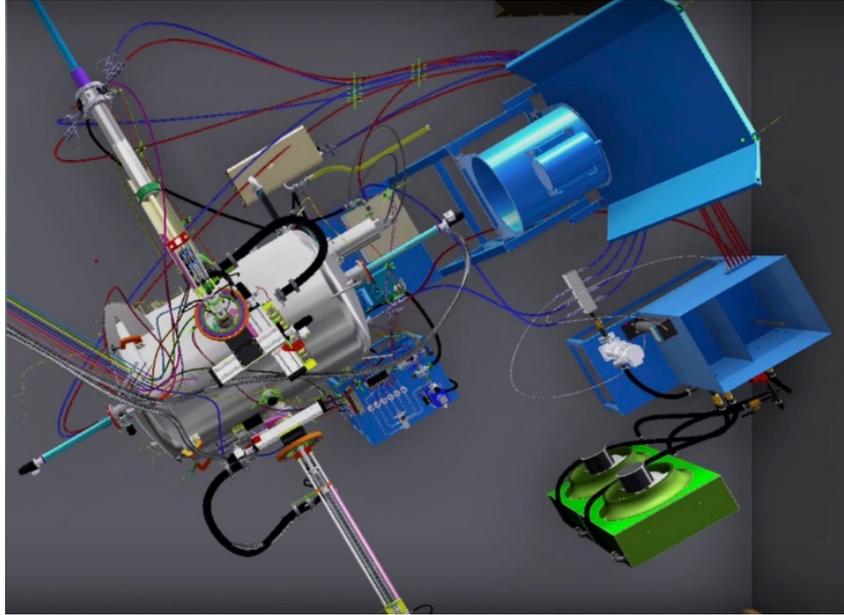


Figure 25. SAFIRE electrical discharge plasma experiment setup [27].

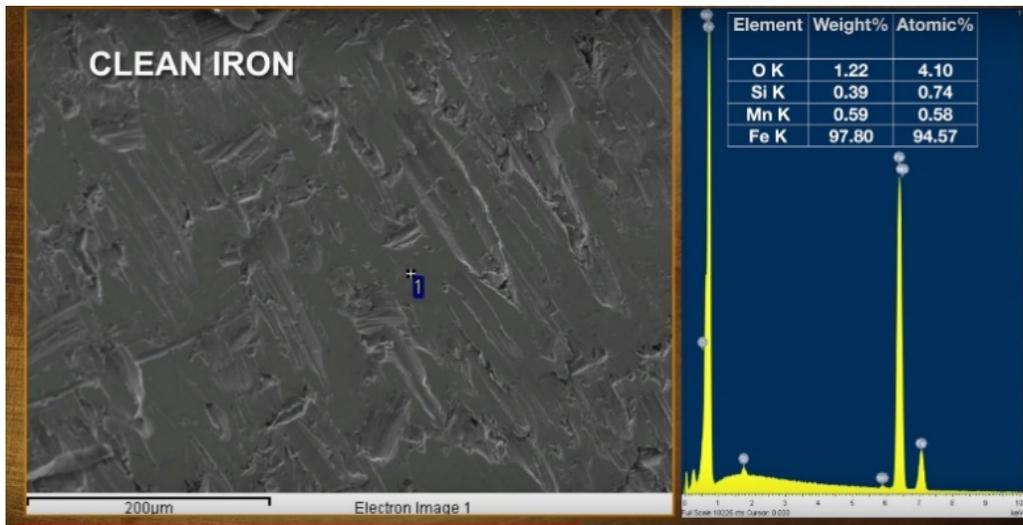




Figure 26. Safire experiment Scanning Electron Microscope (SEM) and x-rays spectroscopy of “clean iron” and possible impurities or suggested transmutations (Ba) after irradiation of iron anode [27].

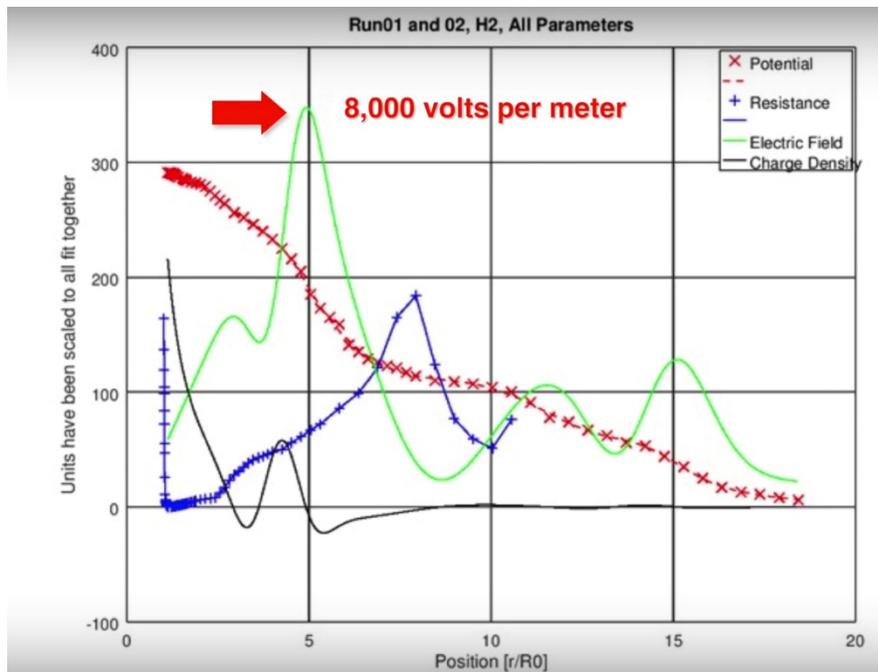


Figure 27. Safire experiment suggested detection of 8 kV / meter electric field in the electric discharge plasma double layers at the anode [27].

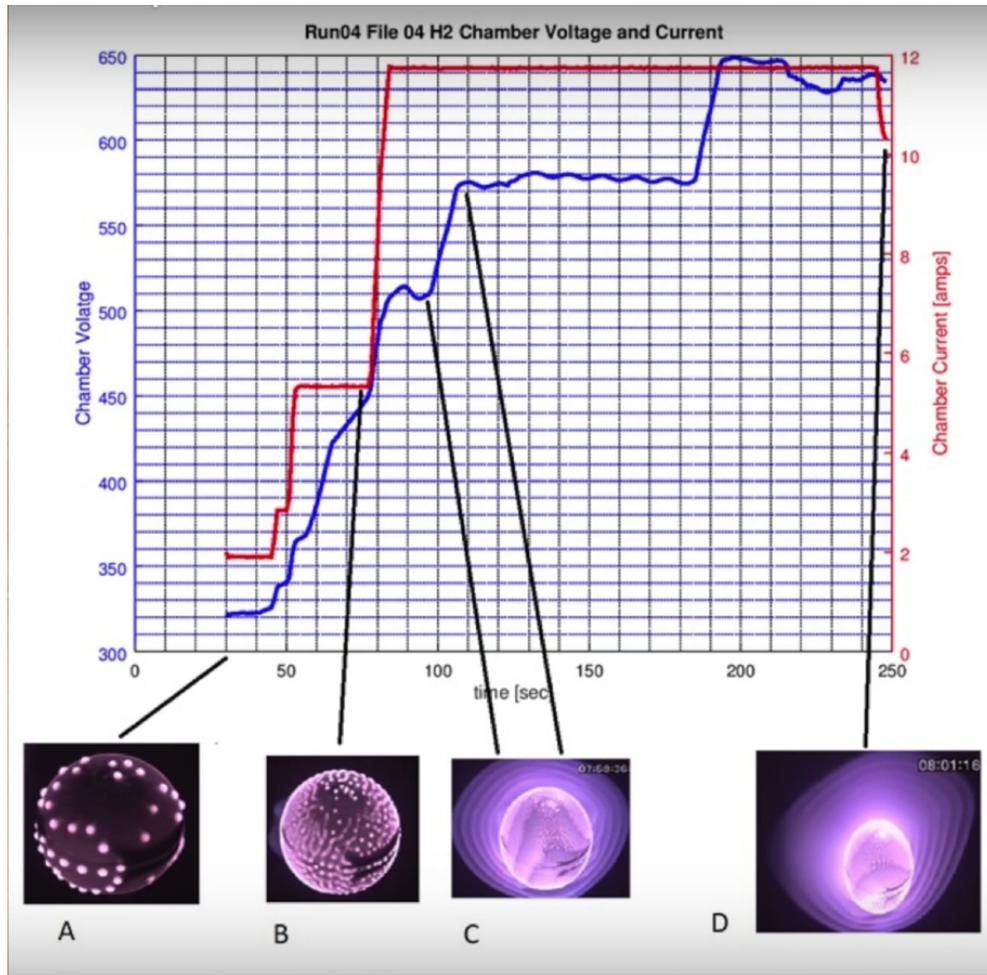
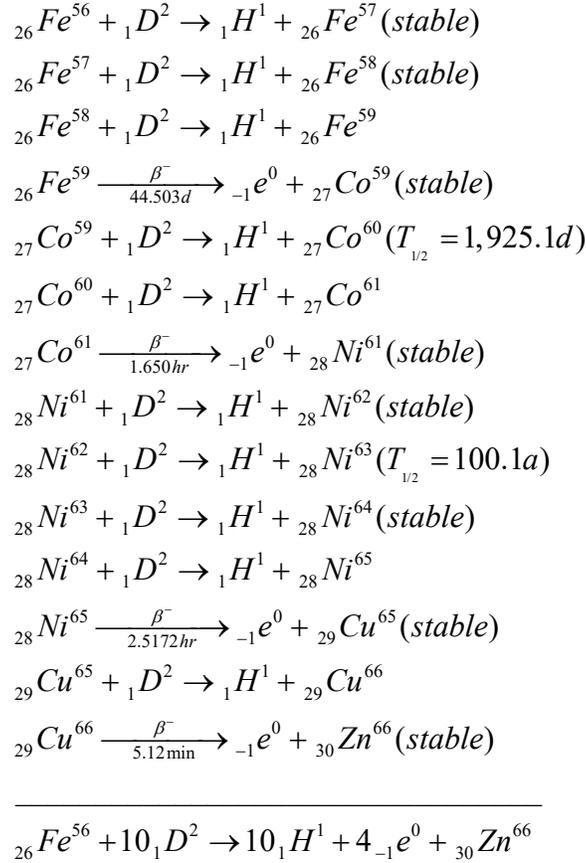


Figure 28. Safire electric discharge experiment modes, voltage and current with anomalous high voltage at constant current input [27].

POSSIBLE Fe^{56} TO Zn^{66} TRANSFORMATION CHAIN WITH D AS A REACTANT

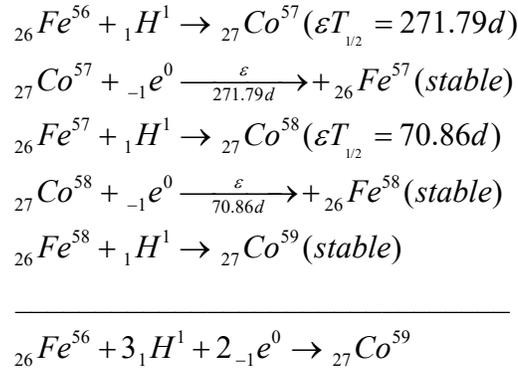
This chain could be expected to occur to the Fe crud from the piping circulating in the experimental fluids generating powerful Co^{60} gamma rays. If the chain is started at the Co^{60} junction, it would be a way of disposing of the crud accumulating in fission power plants piping hot radiation spots.



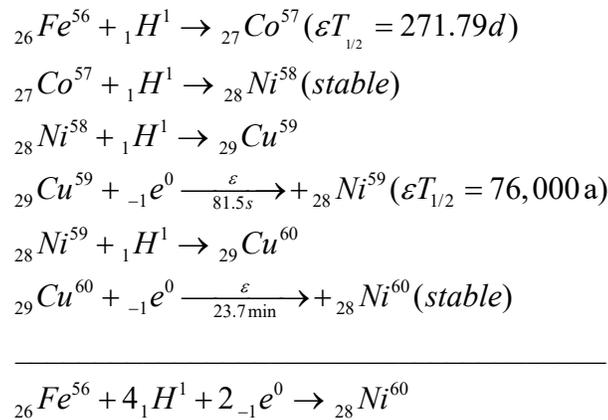
This chain is not successful in explaining the observation of the Ba isotope in the sampling process. Plausible explanations for its observation is that Ba was used as a getter for vacuum tubes and in oxide form as the emissive coating on indirectly heated cathodes. It is added to steel and cast iron to reduce the size of carbon grains within the microstructure. Elemental barium is used as an additive bearing alloys, lead–tin soldering alloys to increase the creep resistance; alloy with nickel for spark plugs; additive to steel and cast iron as an inoculant; and alloys with calcium, manganese, silicon, and aluminum as high-grade steel deoxidizers.

POSSIBLE Fe⁵⁶ TO Co⁵⁹, Ni⁶⁰ TRANSFORMATION CHAIN WITH H AS A REACTANT

As this chain involves proton-rich nuclides, the electron capture and positron emission reactions are expected to predominate. If electron captures do occur:



If electron captures, which have a relatively long half-life do not have a chance to occur:



This chain reaction with Fe leads to Ni⁶⁰, nowhere near Ba, invoking a possible different process at play.

NICKEL / HYDROGEN (Ni/H) DEVICES

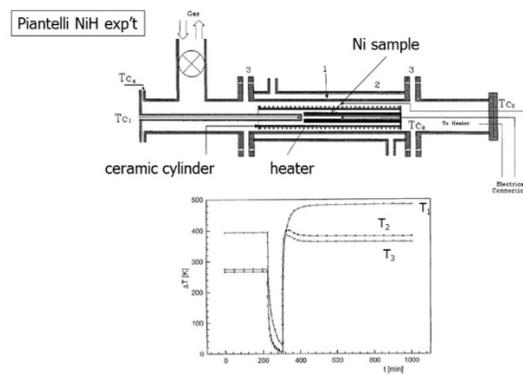


Fig. 4 - A sample excitation performed with a temperature jump for cell B (T₁(A), T₂(A), T₃(B)). An inversion between T₂ and T₃ can be observed. Such an effect is due to the extra power produced by the nickel fuel.

S Focardi et al, Il Nuovo Cimento **111** 1233 (1998)

Figure 29. Ni/H device using an electrical heater system.

Several Condensed Matter Nuclear Science (CMNS) experiments used nickel powder and hydrogen gas and an undisclosed catalyst (possibly lithium-aluminum hydride: $LiAlH_4$) in a non-combustion process to allegedly transmute “Enriched Nickel powder” into copper plus energy. Low energy gamma rays are expected to be emitted from the process. An experimental setup diagram, however shows that both H_2 and D_2 may have been loaded into the electrolytic cell.

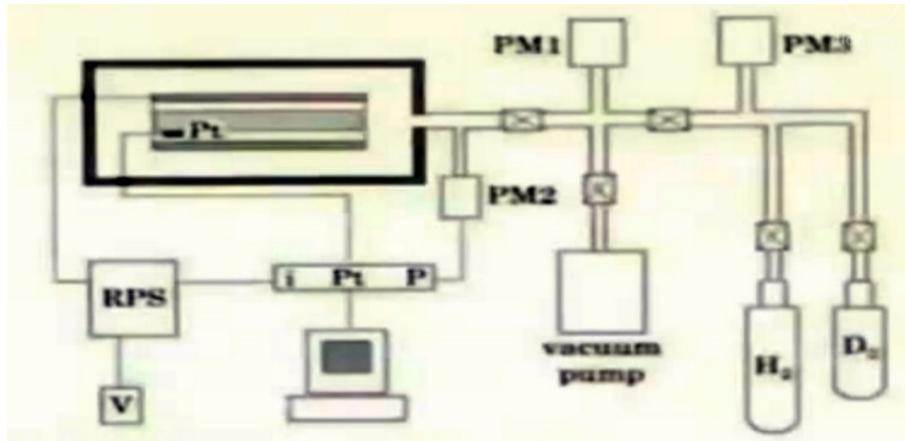


Figure 30. Initial experimental setup which loads both or either hydrogen (H_2) and deuterium (D_2) gases into the electrolytic cell.

Table 4. Stable Nickel naturally-occurring isotopes.

Isotope	Atomic mass [amu]	Natural abundance percent
Ni^{58}	57.9353462	68.0769
Ni^{60}	59.9307884	26.2231
Ni^{61}	60.9310579	1.1399
Ni^{62}	61.9283461	3.6345
Ni^{64}	63.9279679	0.9256

Multiple uses are reported for the Ni isotopes:

Ni^{58} can be used for the production of the radioisotope Co^{58} .

Ni^{60} is used for the production of Co^{57} which is used in bone densitometry and as a gamma camera reference source.

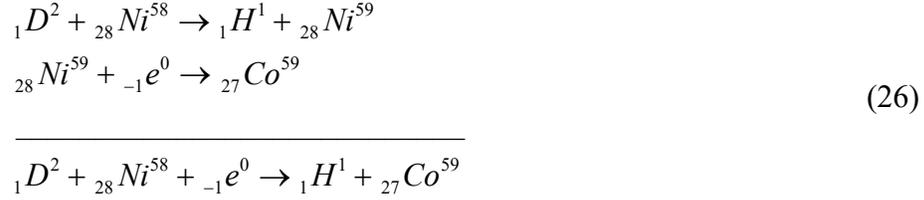
Ni^{60} is also used as an alternative for the production of Cu^{61} , but the route via Ni^{61} is more common.

Ni^{61} can be used for the production of the Positron Emission Tomography (PET) radioisotope Cu^{61} .

Ni^{62} is used for the production of the radioisotope Ni^{63} which can be used as an X-Ray Fluorescence (XRF) source, as an electron capture source in gas chromatographs and as a power source in Micro Electro Mechanical Systems (MEMS).

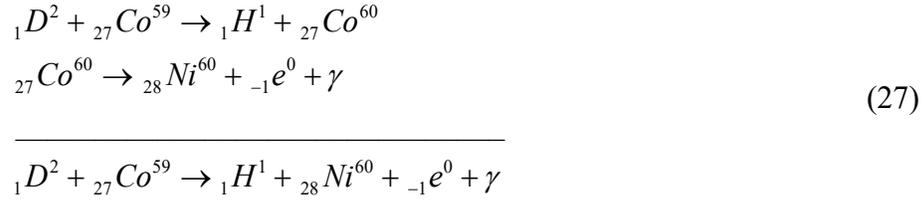
Ni^{64} is used for the production of Cu^{64} used in radio immunotherapy.

If we consider the most abundant isotope of Nickel, ${}_{28}Ni^{58}$ as interacting with a deuteron through deuteron disintegration, bearing in mind that the other nickel isotopes such as Ni^{62} need also careful consideration, one can write:

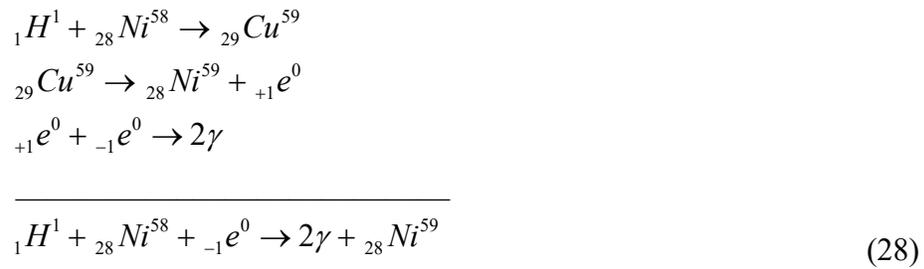


This would result in the production of hydrogen and stable ${}_{27}Co^{59}$ with ${}_{28}Ni^{59}$ acting as a catalyst. Even if hydrogen only is used as reported, deuterium is present in hydrogen at a 160 ppm concentration and would take part in any observed reactions.

Over time the ${}_{27}Co^{59}$ may interact with the deuterons resulting in the ${}_{27}Co^{60}$ isotope emitting strong gammas and turning into stable Ni^{60} ; posing a serious radiation hazard to the device's operators; which apparently was not observed:



On the other hand, if we assume that hydrogen is somehow made to interact with the ${}_{28}Ni^{58}$, overcoming its Coulomb barrier, the following reaction would be assumed:



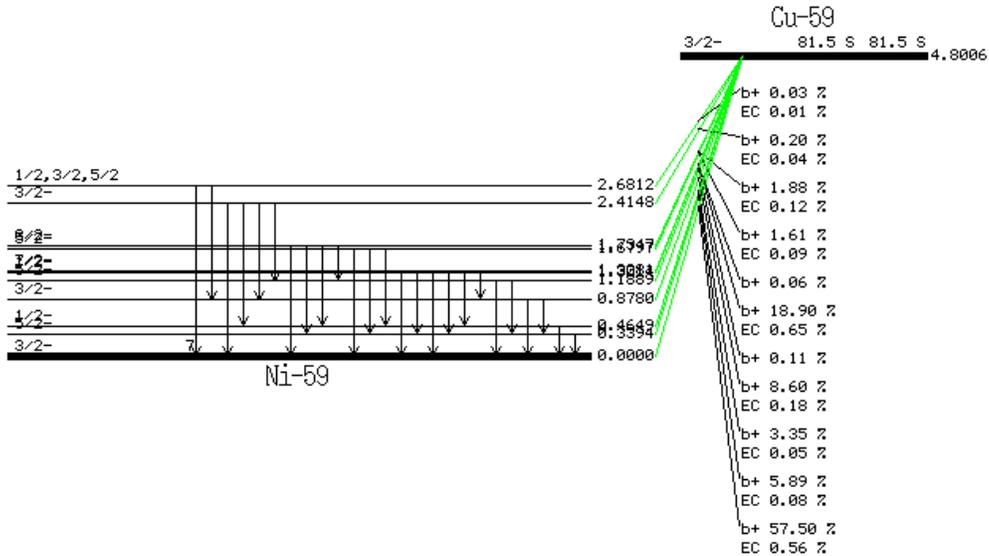


Figure 31. Positron (Beta+ ray: total intensity = 98.1) and electron capture (EC: total intensity = 1.8) decay (decay energy 4.8 MeV) of Cu^{59} (half-life = 81.5 sec) into long-lived Ni^{59} (half-life = 76,000 years).

This implies, if indeed occurring, that transmutation of ^{58}Ni into long-lived pure electron capture ^{59}Ni . Positron-electron annihilation would associate the process with 2 strong gamma rays photons of 0.51 MeV of energy each, in addition to the Cu^{59} gamma emissions, which would be detectable and the device would need to be shielded against gamma radiation, which apparently was not the case, except than aluminum foil was added as heat insulation.

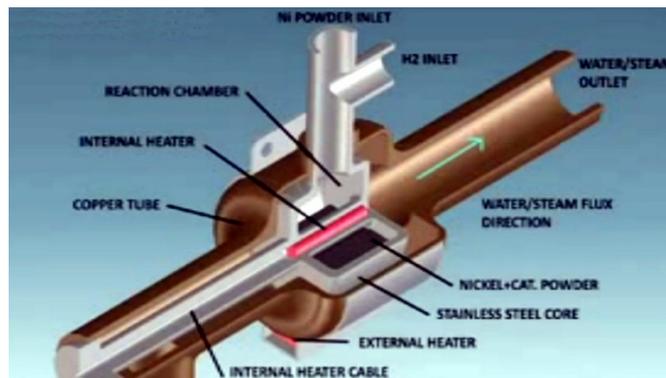


Figure 32. A version of an early Ni/H device. Two units were covered with thermal insulation. The end plug is used for initially charging it with hydrogen before disconnecting it. Water is pumped in at room temperature through a double-walled jacket, and a thermocouple is connected to the chimney of the device to measure the temperature of its produced steam. Electrical current is fed into a resistor inside the device then disconnected. The device allegedly continues to produce heat and generating steam from the cooling water after the inlet current is disconnected.

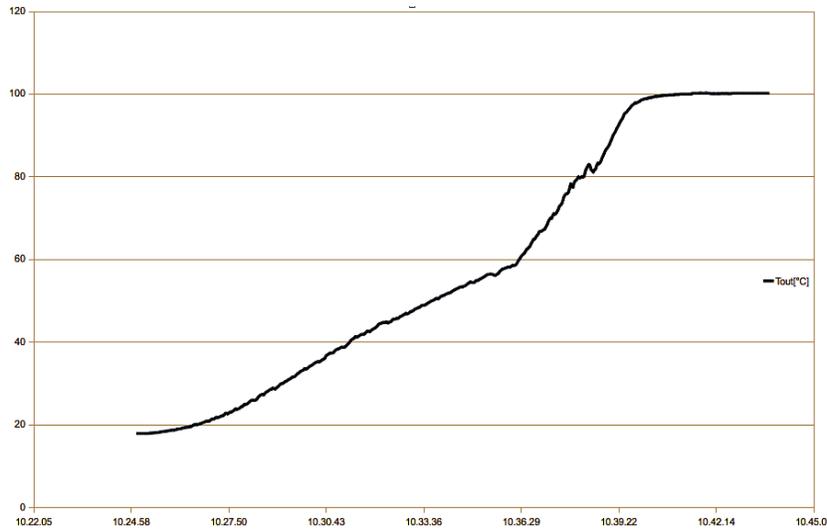


Figure 33. Reported temperature increase at steam outlet of a Ni/H device. Temperature reportedly to have increased above 60 °C with constant electrical power input. Nickel powder is mixed with a “catalyst” that is likely lithium-aluminum hydride LiAlH_4 which breaks down when heated and supplies hydrogen to interact with Ni. Supposedly the reaction requires an unspecified initializing electro-magnetic pulse from the electrical power input.

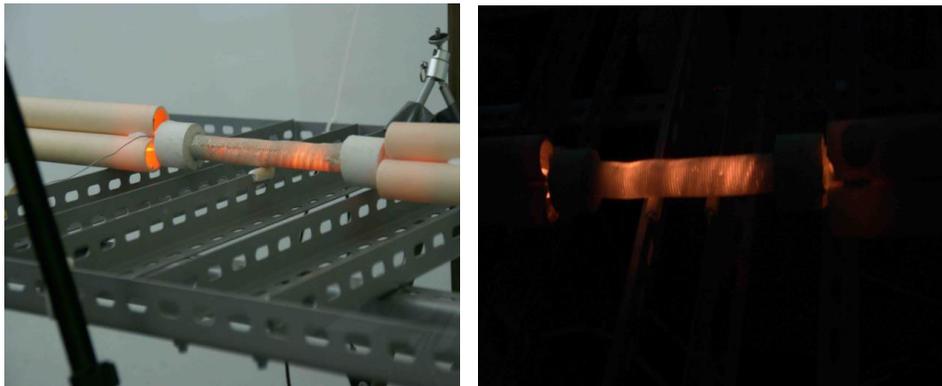


Figure 34. Alternate version of a Ni/H device made of ceramic alumina is reported during operation to be able to withstand temperatures around 1,400 °C. Three-phase electric current is fed from both ends. No attempt is made at collecting the generated heat. The heat signature suggests a spiral coil inner resistor wire configuration [34].

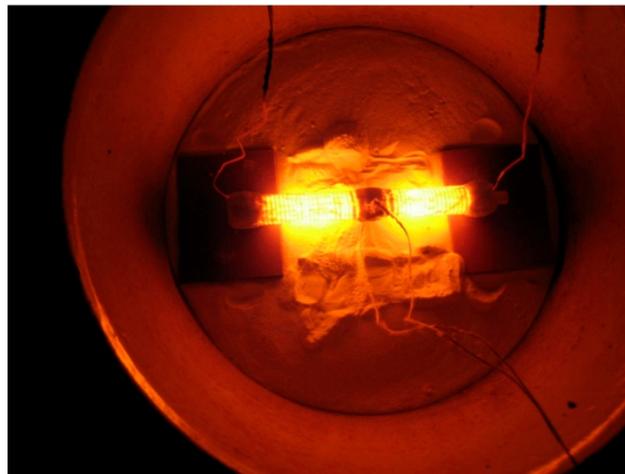
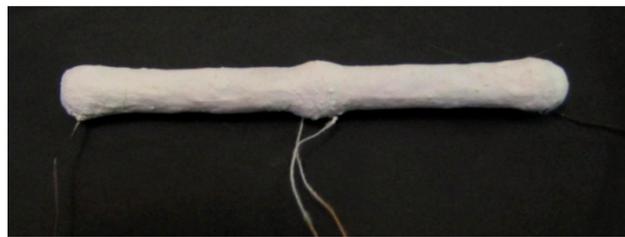
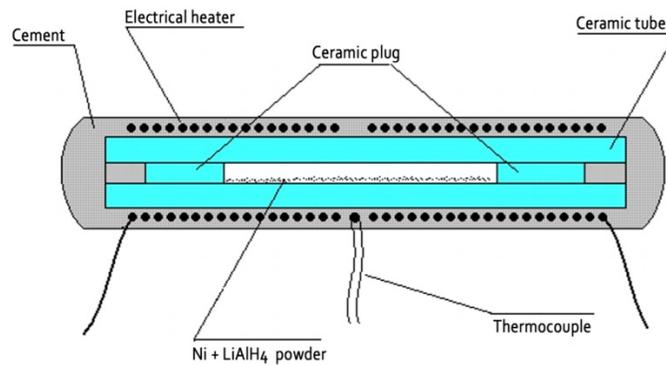


Figure 35. A version of a Ni/H device by A. Parkhomov [37].

The device is filled with hydrogen at a pressure of about 25 bars and was loaded with 50 grams of nickel powder. The process was ‘ignited’ with an electrical resistance. Input power of 330 Watts, of which about 30 Watts were required to operate the electronics. Notice that hydrogen still contains deuterium at a ratio of 160 ppm.

The curve for the water temperature at the output showed a steady increase up to about 60 degrees centigrade, after which the increase escalated. At the same time there was no increase in power consumption, and it decreased when it got warmer. It took nine minutes to go from 20 to 60 °C, which corresponds to the heating from the input electrical power. Going from 60 to 97.5 °C took four minutes.

An output of 470 kWth of power over 3-4 hours was claimed with an energy amplification factor of about 7. The initial claims of a Ni-H₂ interactions were substituted with p-Li⁷ interactions with Ni as a catalyst.

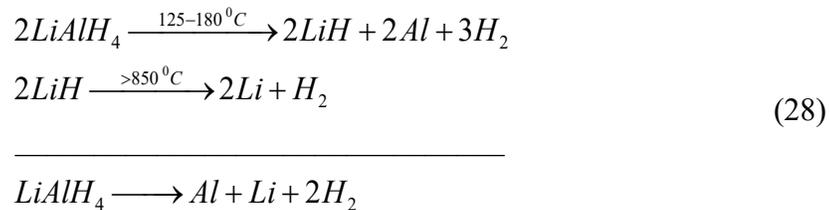
An observation about the reported energy balance is that it may have inadvertently accounted for only the calorimetric electrical energy input and the thermal energy output in the generated steam to estimate an energy amplification factor. It may have missed accounting for the energy provided into the system from the pumped-in hydrogen, which by itself is an “energy carrier,” or an energy storage medium.

Its “effusion” from the nickel in the presence of an oxidizer would release heat. The experiment would thus amount to a fuel cell using the energy stored in the hydrogen to produce heat instead of electricity.

In fact, at some time, fancy cigarette lighters were manufactured in Germany where hydrogen was loaded into a palladium rod. Exposing the tip to air, leads to the process of “effusion” with the tip glowing hot enough for the ignition of a cigarette. If that is the primary process at hand, then the device can be considered as a hydrogen-fueled heat-producing, rather than an electrical-producing fuel cell.

A version of the device was examined by Giuseppe Levi; Bologna University, Bologna, Italy; Evelyn Foschi, Bologna, Italy; Bo Höistad, Roland Pettersson and Lars Tegnér; Uppsala University, Uppsala, Sweden; Hanno Essén; Royal Institute of Technology, Stockholm, Sweden, in a report: “Observation of abundant heat production from a reactor device and of isotopic changes in the fuel,” March 2014 [34].

Pokharov in Russia reported about a replication of the second version of the device [39]. The reactor consisted of a ceramic cylinder of Al₂O₃ with a length of 120 mm, external diameter of 10 mm and internal diameter of 5 mm. An electrical heater is wound around the cylinder. Inside of the cylinder is 1 gm of powder Ni +10% LiAlH₄. A thermocouple is attached at the external surface of the cylinder. The ends are sealed by high temperature resistant cement. The whole cylinder is then covered by the same cement. The following interpretation of the device’s operation is suggested as:



“During the heating, the lithium-aluminum-hydride decomposes. One gram of lithium-aluminum-hydride delivers 0.105 g hydrogen (or 1.17 liters at normal air pressure). If the internal diameter of the fuel cylinder is about 4 mm, the volume is about 2 mL, then 100 mg of lithium-aluminum-hydride deliver about 100 mL at normal conditions (air and temperature). If this 100 mL are compressed to 2 mL, the pressure rises to 50 atmospheres. Additional rise in pressure is contributed by the heat.”

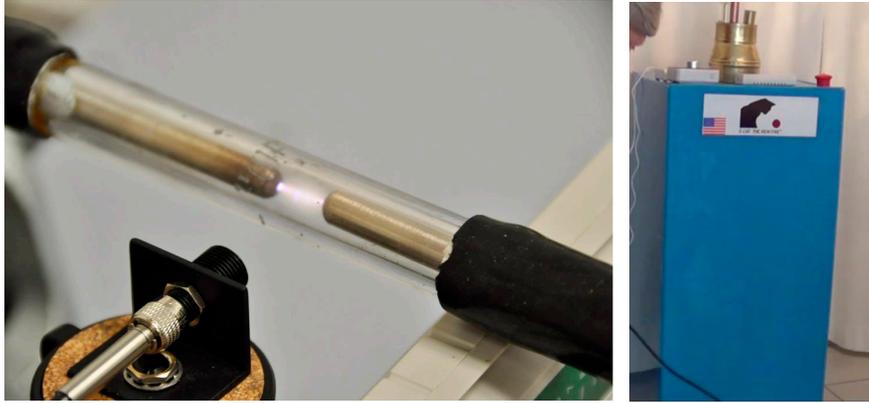


Figure 36. Arc plasma discharge prototype of a possibly Ni/H device. The fact that it is controlled from the internet by the supplier as a 22 kWth heat source, with the heat generation to be sold to the potential customer, is doubtful to attract commercial interest.

BRILLOUIN ENERGY CONTROLLED ELECTRON CAPTURE REACTION (CECR) PROCESS DEVICE

Brillouin Energy Corp. of Berkeley, California, is where researchers are developing what they term a controlled electron capture reaction (CECR) process. In their experiments, ordinary hydrogen is loaded into a nickel lattice, and then an electronic pulse is passed through the system, using a proprietary control system. They claim that their device converts H^1 to D^2 , to T^3 and then to H^4 that they refer to as quatrium, which then decays to He^4 and releases energy. They report that they have confirmed T production in their process.

Brillouin main claim is to have developed a controllable Condensed Matter Nuclear Science (CMNS) reactor with a very low Coefficient of Performance COP of 1.2-1.4, producing a few watts of thermal power only [35].

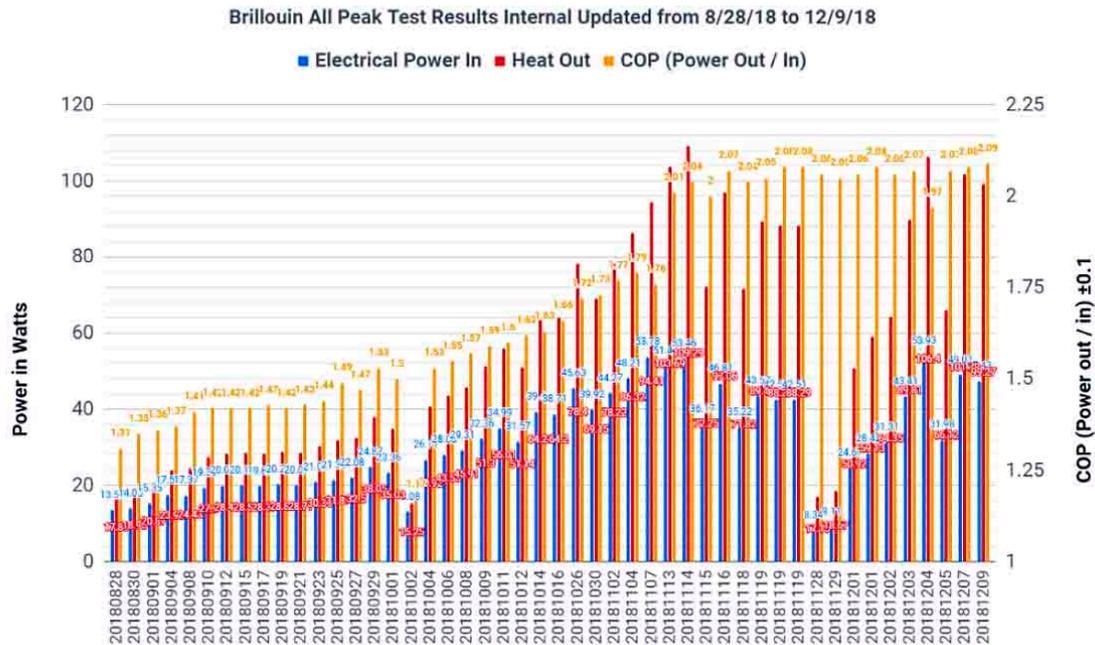


Figure 37. Coefficient of Performance [COP] as reported by Brillouin Energy [35].

Brillouin Energy lost the attention of its audience with reference to complex issues of “Q waves,” generating “quadrinos,” maybe forming dark matter and possibly having an “alternate universe of fractional electron orbitals.”

ATTEMPTED APPROACHES TO CONDENSED MATTER NUCLEAR SCIENCE (CMNS)

Several approaches can be identified in the pursuit of Condensed Matter Nuclear Science (CMNS):

1. Electrochemistry: Using PdD / LiOD as reactants.
2. Metal / hydrogen gas systems: Combinations of (H, D, T, Li), (Pd, Ni, Zr, Ti, Ta, Nb).
3. Metal-gas modulated plasma: Glow discharge.

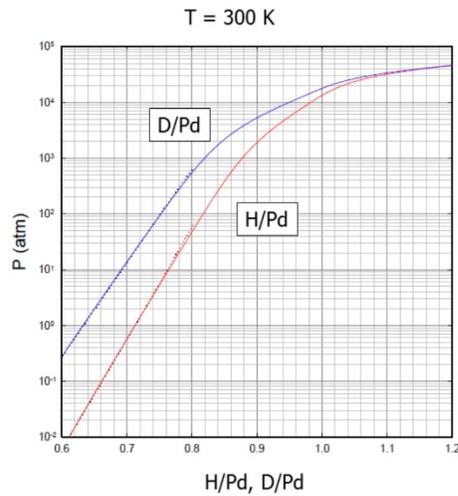
Palladium-deuterium systems, and nickel-hydrogen systems have different parameters. Once the parameters are known, the systems are reported by experimenters to be reproducible.

The ability of Pd to absorb hydrogen was recognized in the 19th century. In 1927, Swedish scientist J. Tandberg claimed that he had fused hydrogen into helium in an electrolytic cell with palladium electrodes. On the basis of his work he applied for a Swedish patent for "a method to produce helium and useful reaction energy". After deuterium was discovered in 1932, J. Tandberg continued his experiments with D₂O.

In the late 1920s, two German scientists, F. Paneth and K. Peters, reported on the transformation of hydrogen into helium by spontaneous nuclear catalysis when H is

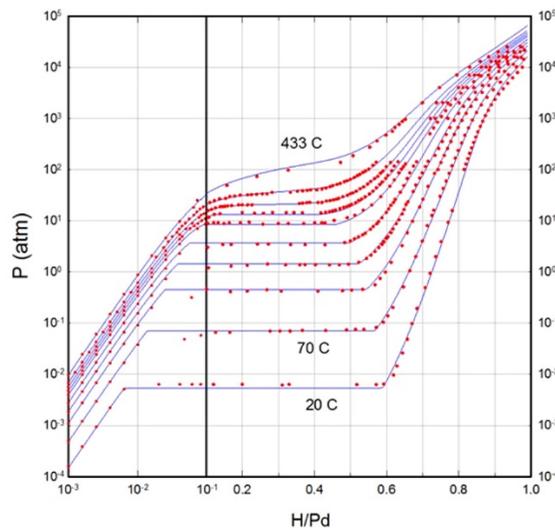
absorbed by finely divided Pd at room temperature. These authors later acknowledged that the helium they measured was due to background from the air. Due to Paneth and Peters' retraction, Tandberg's patent application was denied [42].

NUCLEAR TRANSMUTATION OBSERVATIONS IN A D/Pd SYSTEM IN JAPAN



P. L. Hagelstein, J Cond Mat Nucl Sci **17** 35 (2015)

Figure 38. Loading of D and H in a Pd lattice at 300 K.



P. L. Hagelstein, J Cond Mat Nucl Sci **20** 54 (2016)

Figure 39. Loading of Hydrogen in palladium hydride at different pressures and temperatures.

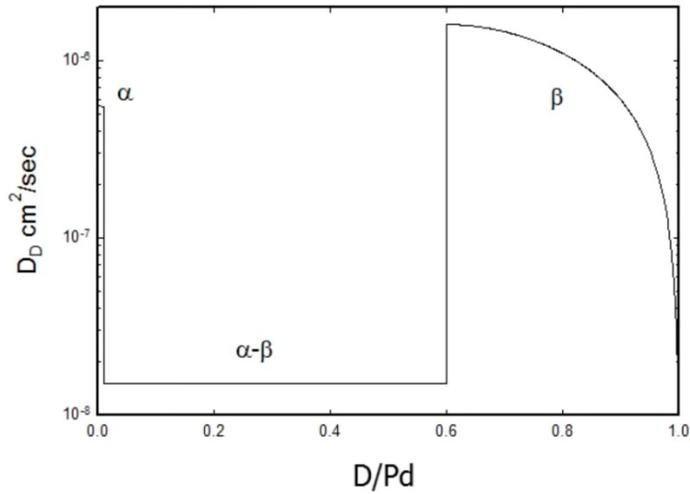


Figure 40. Diffusivity of D in Pd. A miscibility gap exists within the α - β phase. It is easy to load D into Pd within the range $D/Pd=0.6-0.7$, but difficult for $D/Pd>0.9$.

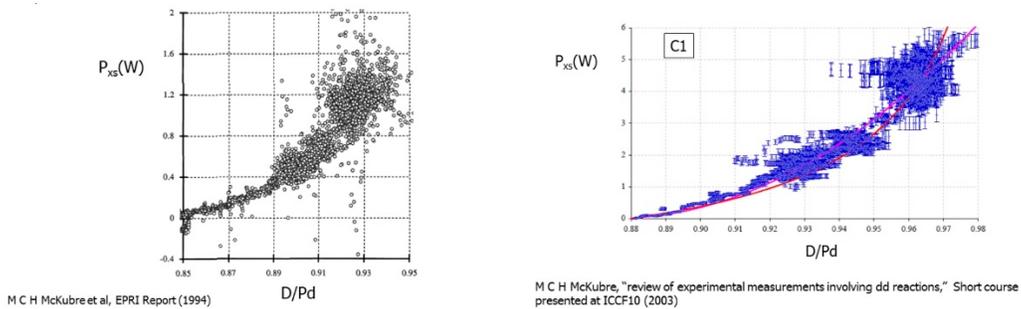
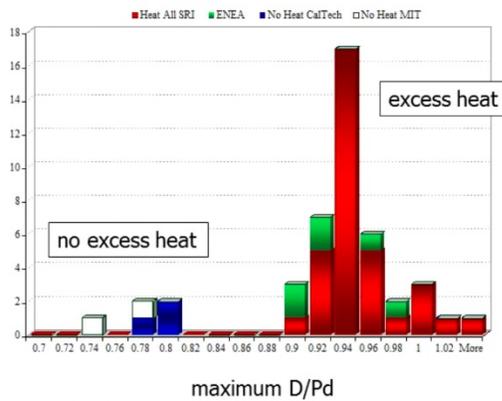
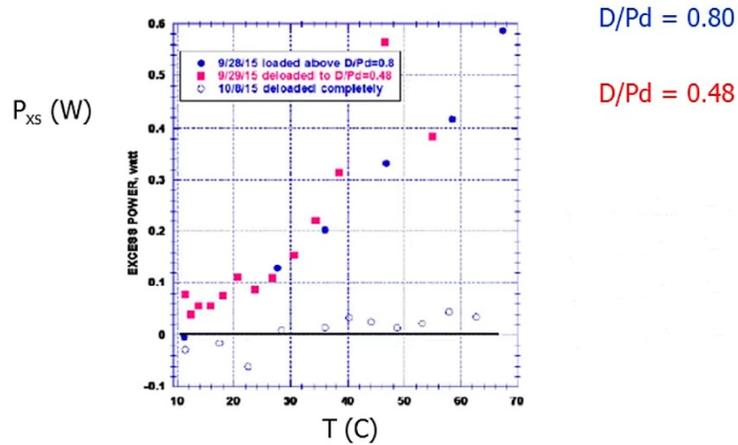


Figure 41. Power in watts for different deuterium into palladium loadings in experiments at SRI International (Stanford Research Institute), San Diego, CA, USA. Three loading regions appear suitable for excess heat generation.



M. C. H. McKubre Proc. ICCF15 (2009).

Figure 42. D/Pd loading levels at SRI International (Stanford Research Institute)/EPRI (Electric Power Research Institute), CalTech, ENEA, and MIT.



E. Storms, J Cond. Mat. Nucl. Sci. **20** 100 (2016)

Figure 43. Heat generation observed in high and low loadings.

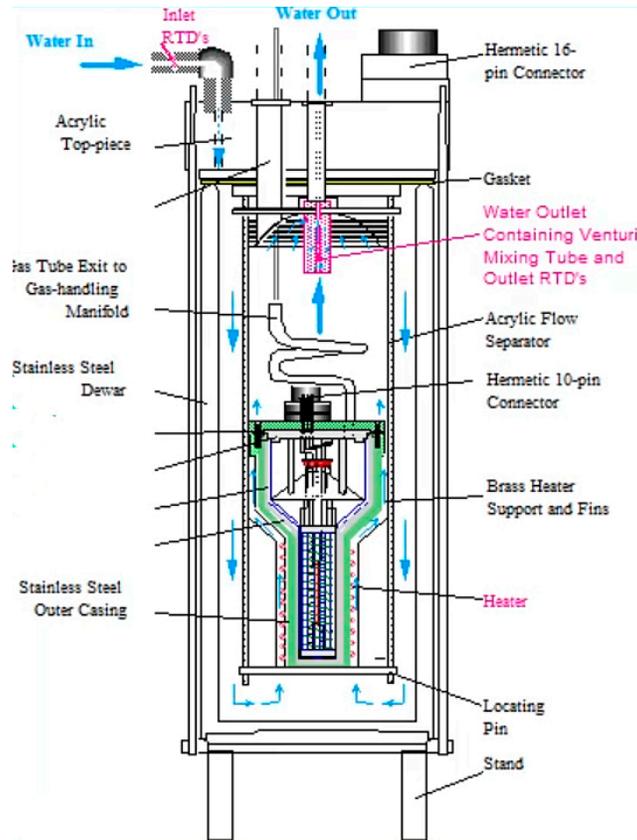


Figure 44. Flow Calorimetry at SRI International (Stanford Research Institute) experiments.

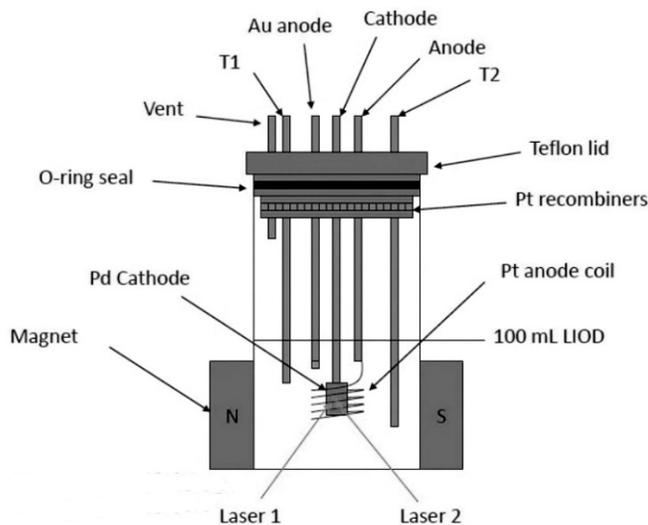


Figure 45. Electrolysis assisted with external magnetic fields and/or laser beams. Source: Dennis G. Letts, Dennis Cravens, and Peter L. Hagelstein, “Progress on Dual Laser Experiments.”

NUCLEAR TRANSMUTATIONS EXPERIMENTS INTERPRETATION [40, 41]

A nuclear transmutations approach described by Y. Iwamura, M. Sakano and T. Itoh uses a host material described as a “nano-structured thin-film composed of palladium and calcium oxide and palladium substrate, with a target element” planted between the layers.

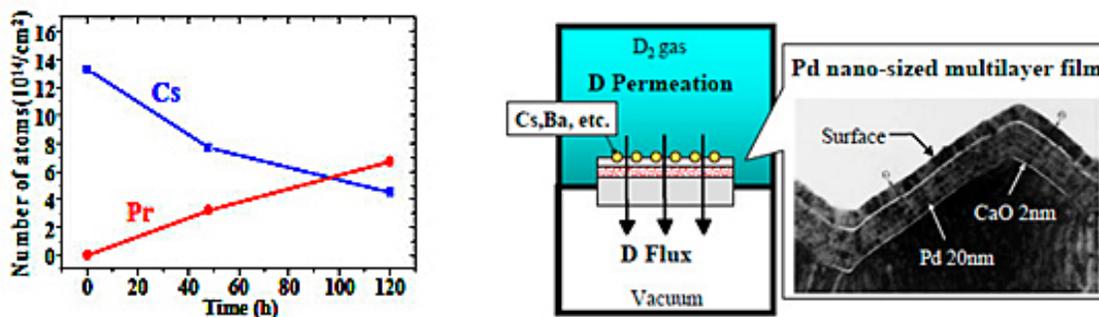


Figure 46. D₂ gas permeation through nano-structured Pd multilayered film under low temperature and pressure. Nuclear transmutation attempts of Cs into Pr work at Mitsubishi, Japan. Y. Iwamura M. Sakano and T. Itoh, *Jpn. J. Appl. Phys.* 41, 4642-4648, 2002.

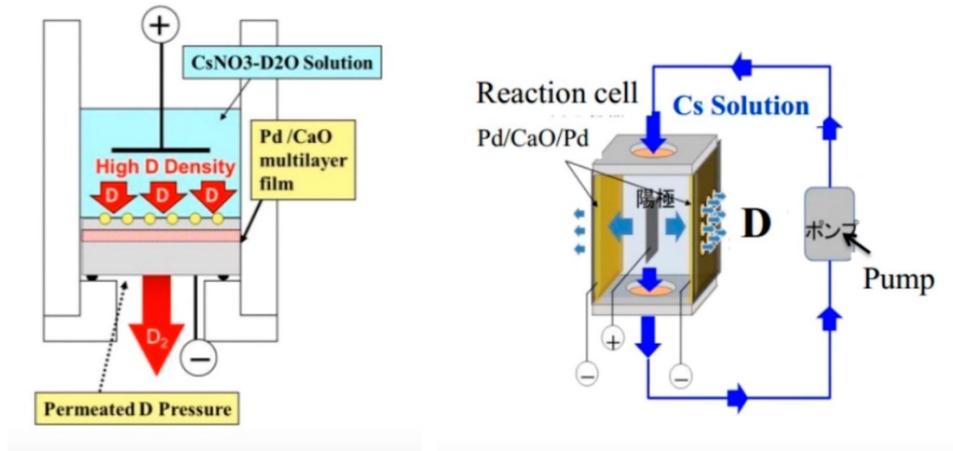


Figure 47. Cs^{133} transmutation experiments. Left: Batch approach with addition of fixed quantity of Cs^{133} . Right: Continuous flow circulation of electrolyte approach. Source: Y. Iwamura, Technology and Innovation Headquarters, Mitsubishi, Japan.

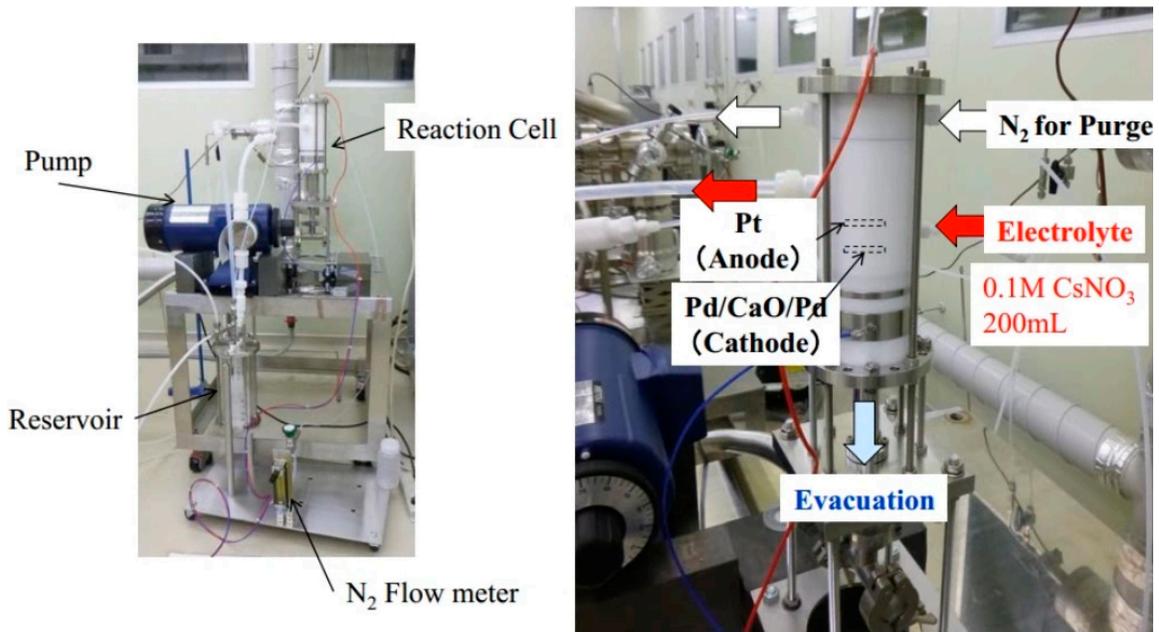


Figure 48. Cs^{133} transmutation experimental setups. Source: Y. Iwamura, Technology and Innovation Headquarters, Mitsubishi.

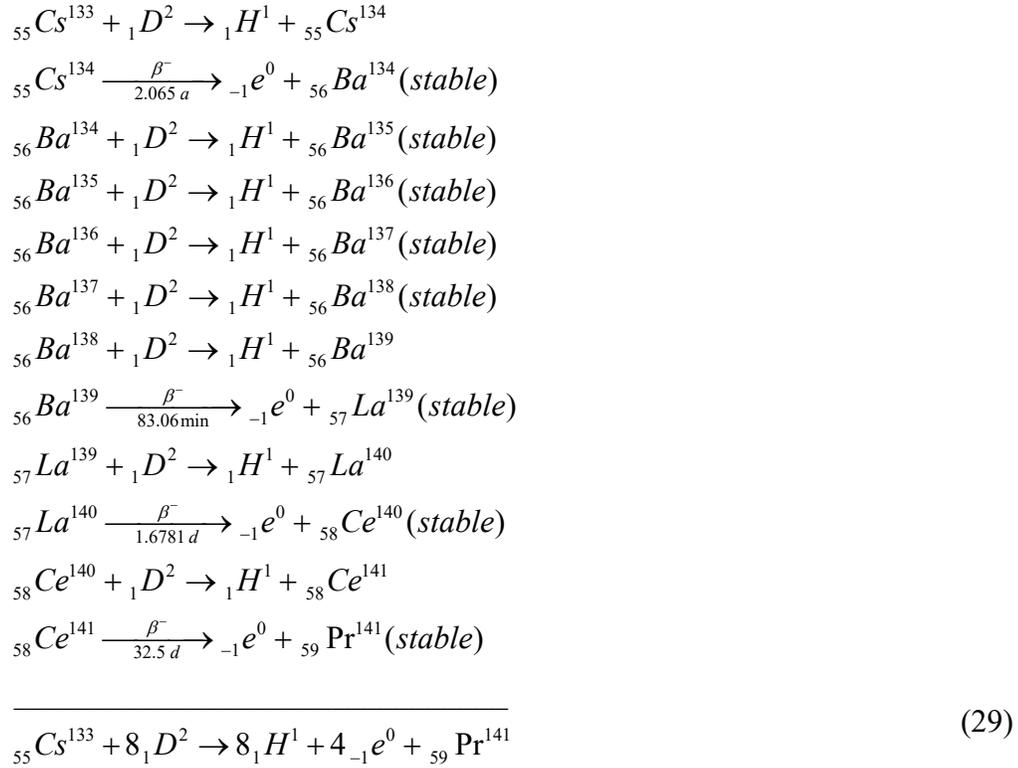
A typical target element of Cesium is reported to be transmuted into Praseodymium. Barium transmuted into samarium and tungsten into platinum.

Yasuhira Iwamura cannot explain the mechanism of the reaction behind these results, but he does reveal an experimental fact that should give theorists a clue in trying to construct a model of the reaction:

“We observe 2 or 4 or 6 deuterons make fusion for the target materials. The exact mechanism for the transmutation is not clear, of course, but I speculate that two deuterons are related to helium.” “A helium atom consists of two protons and two neutrons, and two deuterons consists of two protons and two neutrons. So I suspect that this kind of mechanism exists in this type of transmutation reaction.” A “very small amount of foreign element like impurity plays a very important role to induce condensed matter nuclear reactions.” “In the case of our type of transmutation reactions, if we put calcium oxide onto the palladium thin-film, near the surface area, transmutation reactions occur, but if we use palladium only, we cannot observe a transmutation reaction.” “It is just a speculation, but I speculate that the interface between the foreign element, like calcium oxide, and the main element like the palladium, at the near surface plays a very important role. The mechanism is not so clear, but I suspect this kind of mechanics is behind condensed matter nuclear reactions.”

Answering the call for an alternative model to the above description, an explanation of the observed experimental results of decreasing ^{133}Cs (Cesium, stable, 100 % natural abundance) isotope concentration associated with an increase in the ^{141}Pr (praseodymium, stable, 100 % natural abundance) isotope concentration in Fig. 46 can be attempted on the basis of our proposed following chain reactions. Not shown are the gamma and antineutrino emission.

POSSIBLE Cs^{133} to Pr^{141} TRANSFORMATION CHAIN USING D AS A REACTANT

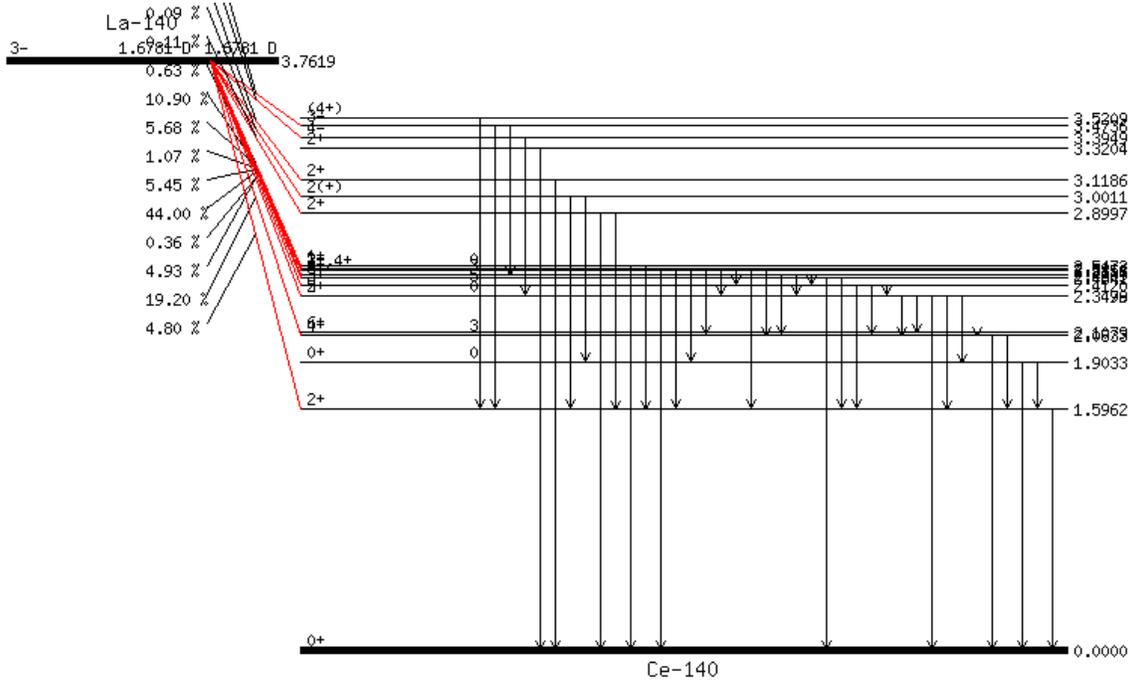
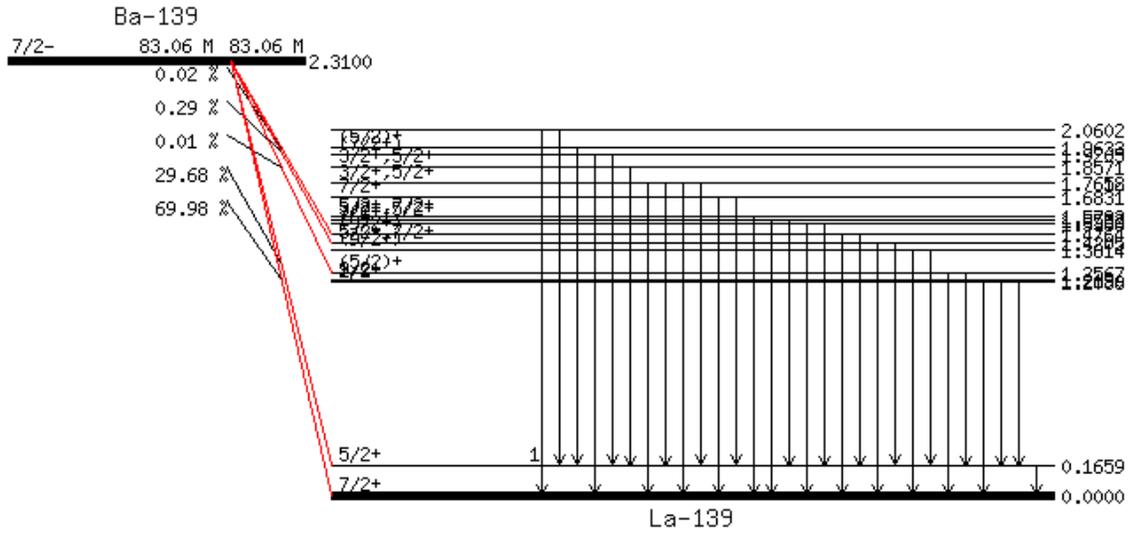
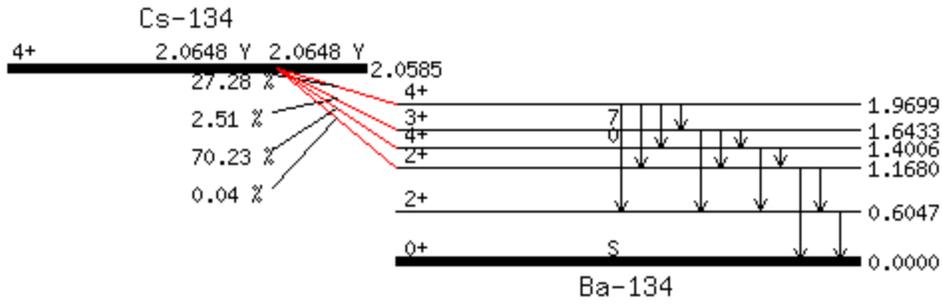


Deuterium acts as a neutron donor to stable nuclides, whose nuclei become neutron rich and try to reach stability by emitting a negative beta particle.

The isotopes cancelling from both sides of the equations act as catalysts in the overall reported experimental result. The appearance of numerous stable isotopes suggests vicinity of a closed stable shell in the nucleus. The proposed explanation is based on conventional nuclear physics without invoking exotic unobserved processes, other than conventional radioactive decay and the suggested Oppenheimer-Philips process leading to Deuteron disintegration.

Electron and hydrogen emission should be accompanying these reactions as well as gamma radiation associated with the decay of the four intermediate decay processes of ${}_{55}\text{Cs}^{134}$, ${}_{56}\text{Ba}^{139}$, ${}_{57}\text{La}^{140}$ and ${}_{58}\text{Ce}^{141}$, whose decay diagrams are shown below.

The copious energetic gamma rays emissions would require health physics protection measures for the experimenters or operators. The electrons would probably be attenuated in the substrate material, maybe generating x-rays through the bremsstrahlung process. The gamma and x-rays emissions may perhaps be attenuated in a surrounding blanket and the heat generated converted into electrical energy in some thermodynamic, **thermoelectric or thermionic cycle. It is not clear whether the resulting hydrogen would be released from the lattice structure and captured for feeding into a fuel cell cycle.**



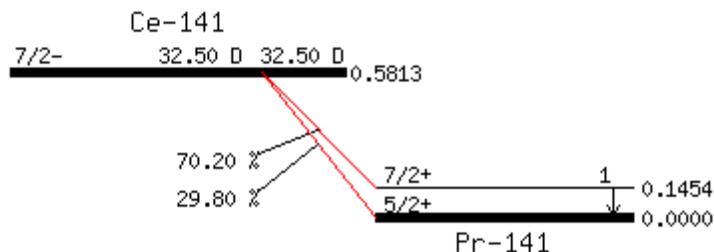
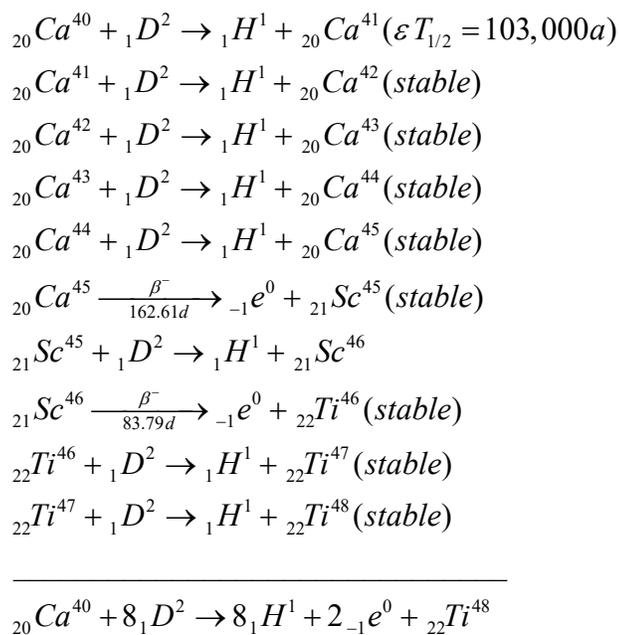


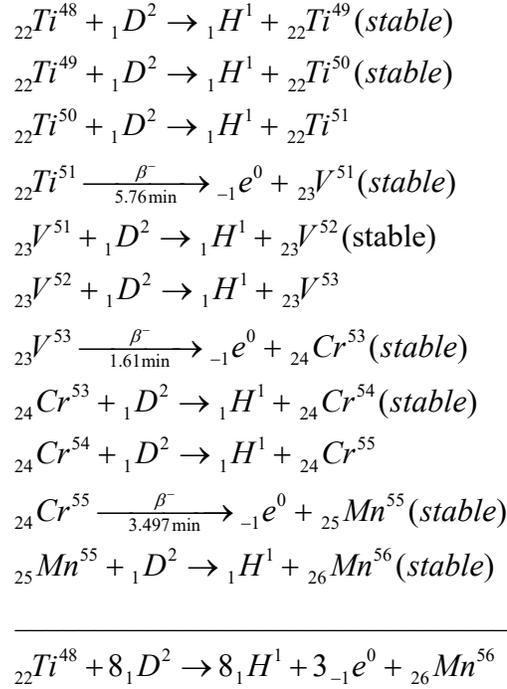
Figure 49. Decay diagrams showing the beta and gamma rays emissions from the $_{55}\text{Cs}^{134}$, $_{56}\text{Ba}^{139}$, $_{57}\text{La}^{140}$ and $_{58}\text{Ce}^{141}$ radioactive species. Only the main decay branchings are considered.

POSSIBLE Ca^{40} TO Ti^{48} TRANSFORMATION CHAIN USING D AS A REACTANT



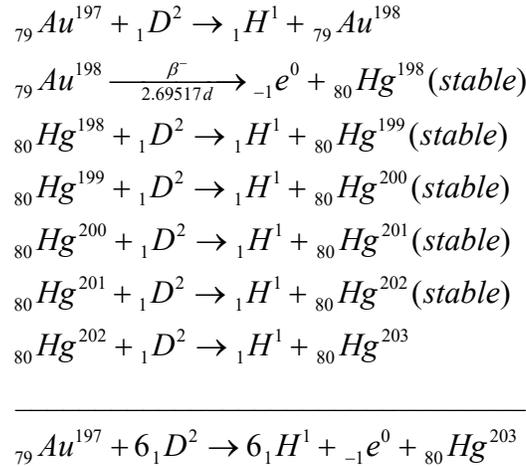
POSSIBLE Ti^{48} TO Mn^{56} TRANSFORMATION CHAIN USING D AS A REACTANT

Because of Ti's affinity to H and D, it has been used as a substitute electrode to Pd.



POSSIBLE Au¹⁹⁸ TO Hg²⁰³ TRANSFORMATION CHAIN USING D AS A REACTANT

An experimenter using Au as a cathode will observe it on short-notice within days melting away as Hg, confirming the transformation process.



TRANSMUTATIONS FOR RADIOACTIVE WASTE CLEANUP [40, 41]

The success of the Japanese CMNS research program is unmatched by any other country. Financial support is provided by industry as well as by the Japanese government organization NEDO, the New Energy Development Organization. Research is actively conducted by dedicated researchers at Tohoku University and at Kobe University by Akito Takahashi and Akira Kitamura.

Yasuhiro Iwamura describes research at Tohoku University supported by both Mitsubishi and Clean Planet, Inc. Clean Planet Chief Executive Officer (CEO) Hideki Yoshino has organized several collaborative efforts with academia and industry in Japan with the hopes of engineering an ultra-clean energy technology, and transmuting radioactive waste into benign materials such as the transmutation experiments using the stable non-radioactive isotope Cesium¹³³.

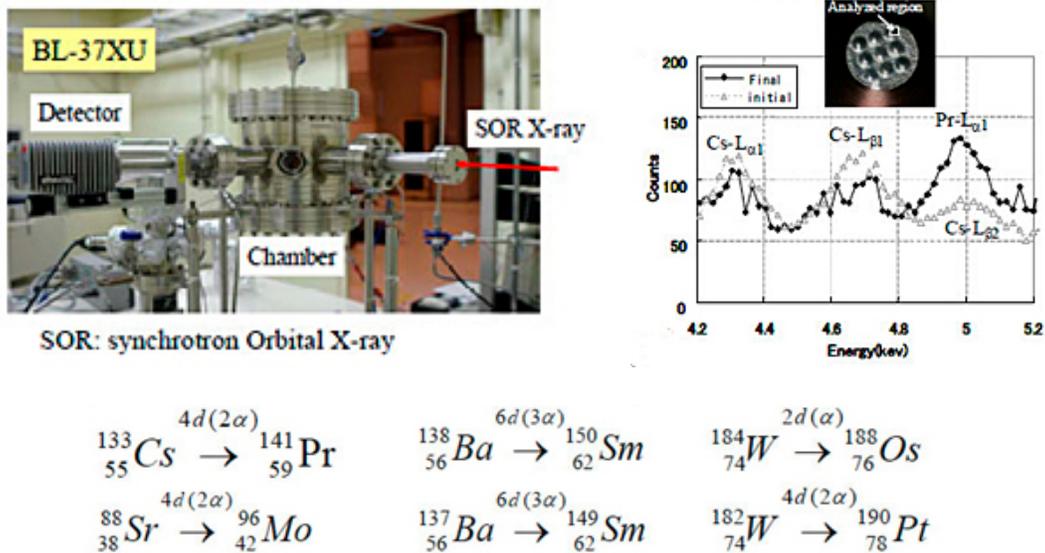
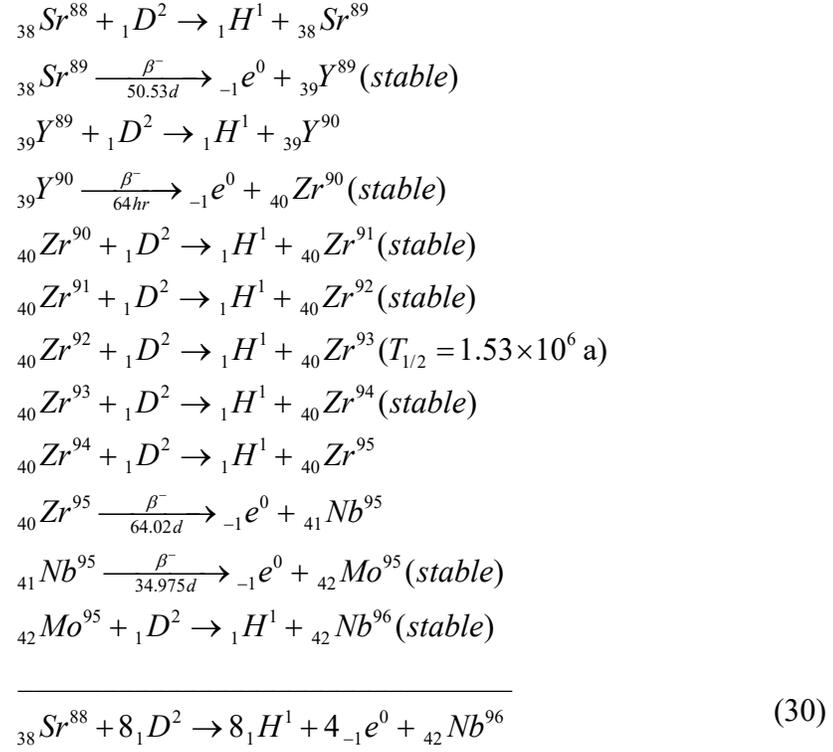


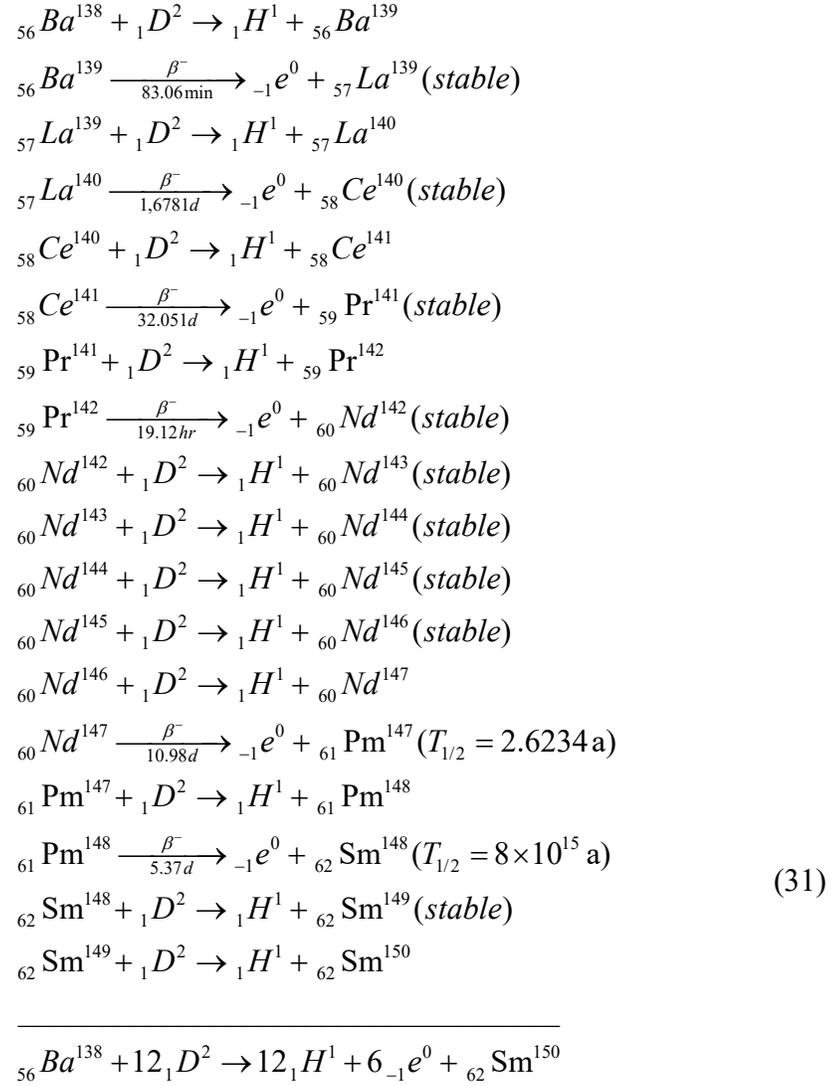
Figure 50. Reported attempts at transmutation of radioactive waste isotopes using D₂ at Mitsubishi, Japan. Y. Iwamura et. al., J. Condensed Matter Nucl. Sci., vol. 4, pp. 132-144, 2011.

The transmutation work is reported to have been replicated by other institutions such as Toyota R&D, and is still in its early research stages. We have already advanced a model for the observed Cs¹³³ to Pr¹⁴¹ transformation. We now attempt application of our model to the other reported transformations.

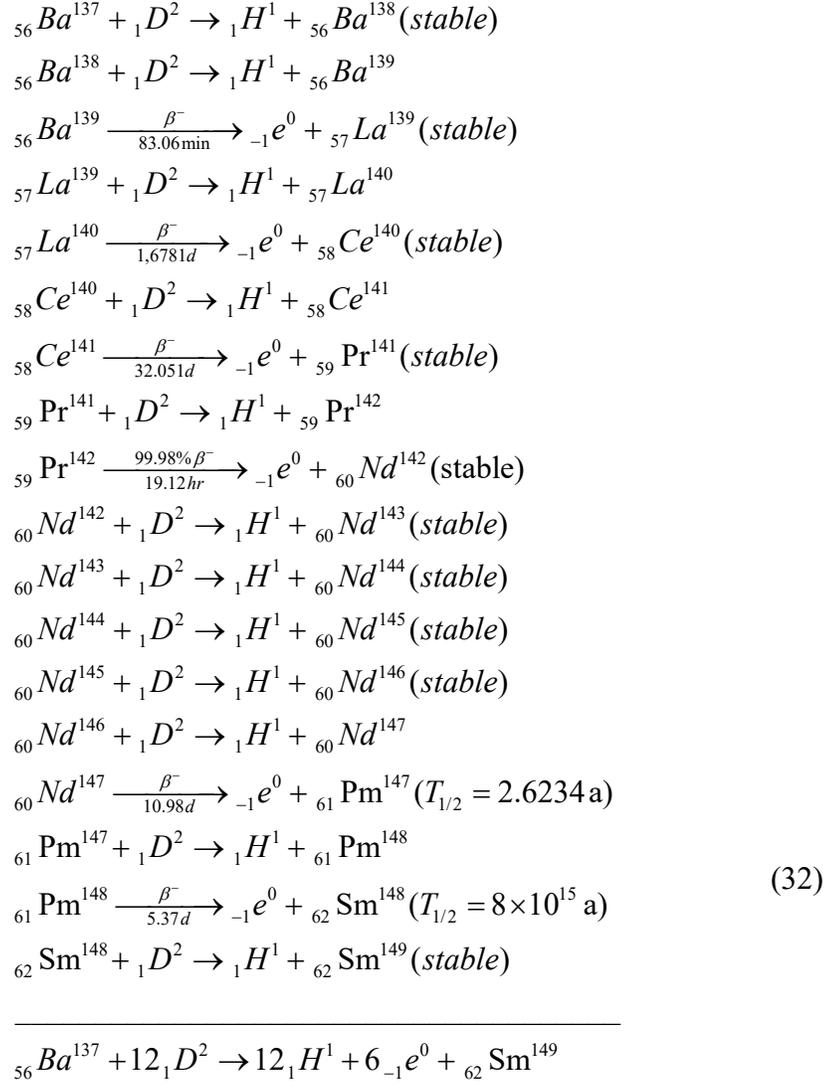
POSSIBLE Sr⁸⁸ to Mo⁹⁶ TRANSFORMATION CHAIN USING D AS A REACTANT



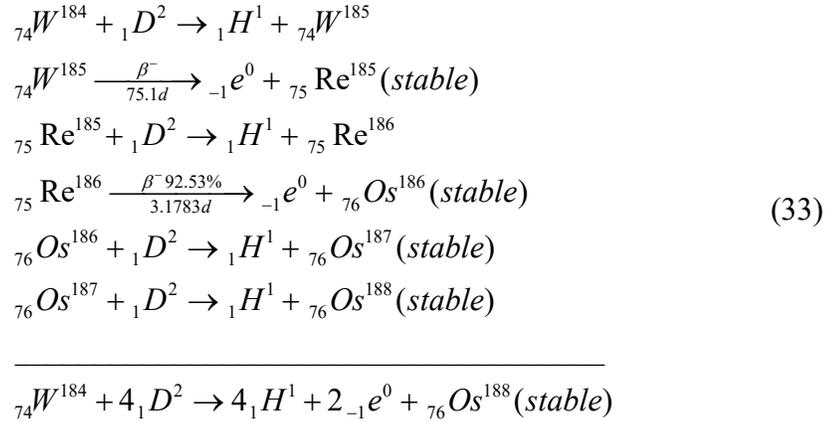
POSSIBLE Ba¹³⁸ to Sm¹⁵⁰ TRANSFORMATION CHAIN USING D AS A REACTANT



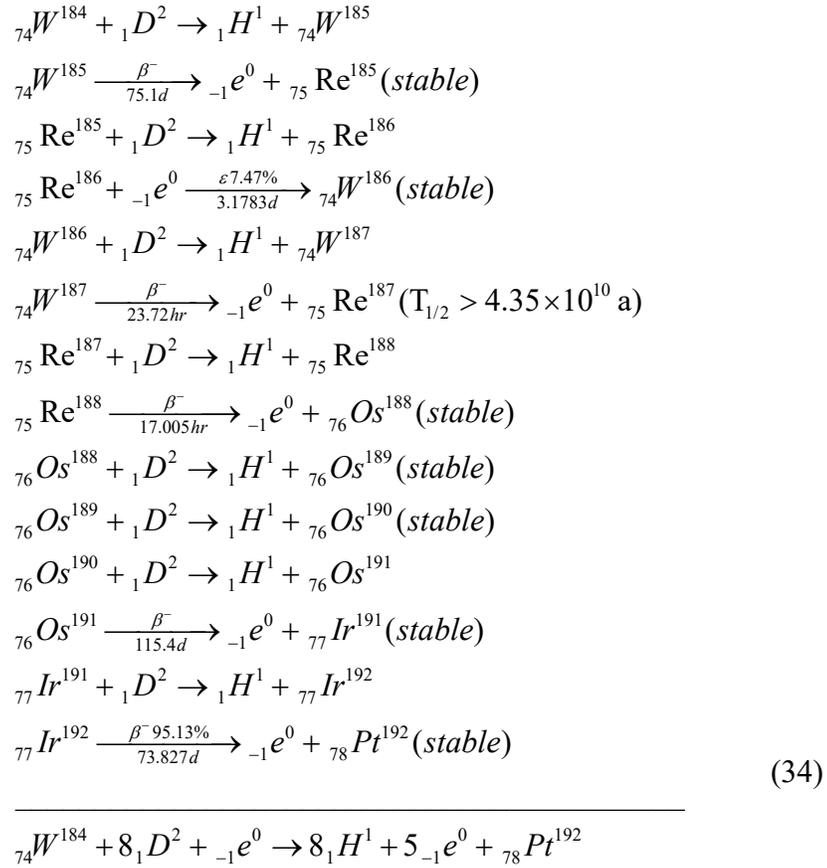
POSSIBLE Ba¹³⁷ to Sm¹⁴⁹ TRANSFORMATION CHAIN USING D AS A REACTANT



POSSIBLE W¹⁸⁴ to Os¹⁸⁸ TRANSFORMATION CHAIN USING D AS A REACTANT

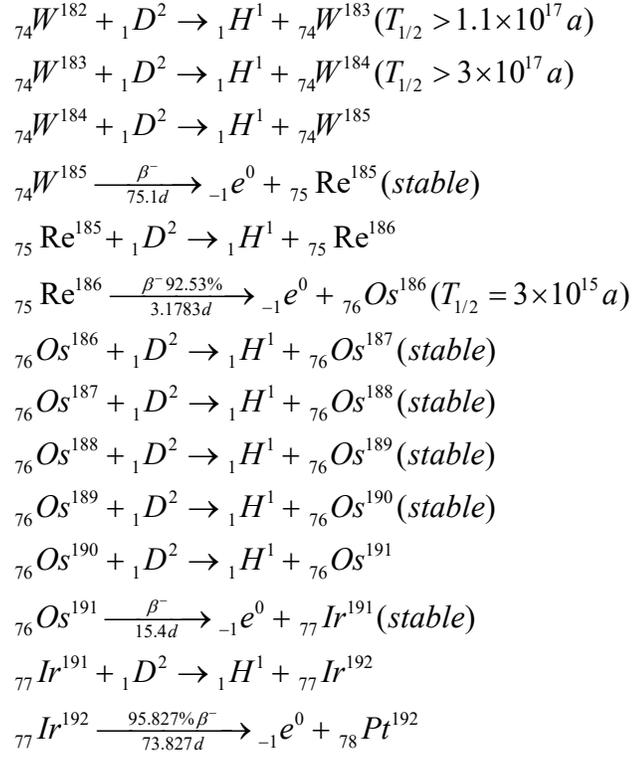


One can follow the branching chain of Re^{186} as:

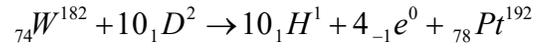


POSSIBLE W^{182} to Pt^{192} (Pt^{190} ?) TRANSFORMATION CHAIN USING D AS A REACTANT

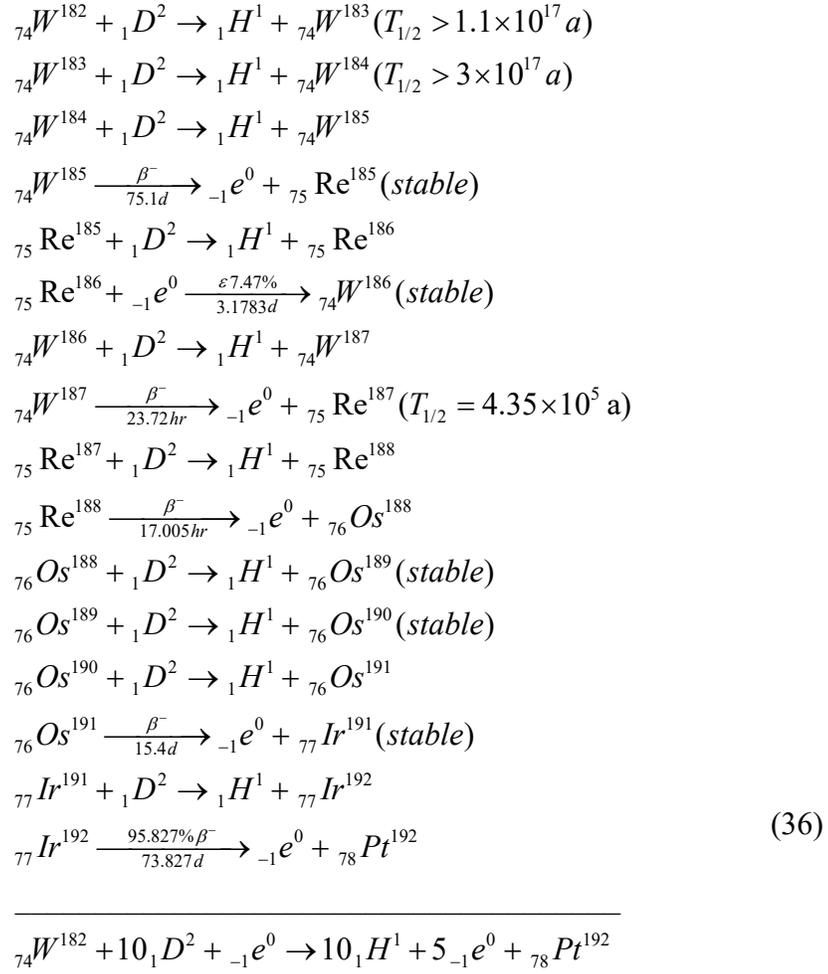
This is an anomalous result since the experimental result predict a chain that ends with the Pt^{192} isotope in contradiction to the experimental result of Pt^{190} . The proposed theoretical model perfectly predicts the experimental observations in 5 out of six cases but diverges only in the single case of W^{182} , predicting the occurrence of Pt^{192} rather than Pt^{190} , and suggesting a need to revisit the data used in the respective conclusions.



(35)



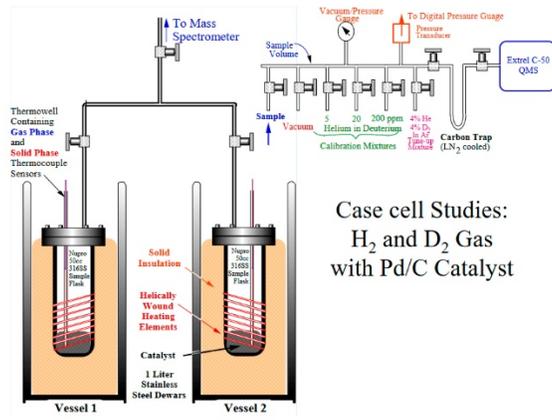
One can follow the branching chain of Re^{186} as:



This branching rejoins the main chain at the Os¹⁸⁸ node. It also eventually converges to Pt¹⁹² like the main chain.

SRI INTERNATIONAL (STANFORD RESEARCH INSTITUTE) DEUTERIUM D/Pd AND HYDROGEN H/Pd COMPARISON [38]

An experimental electrochemistry process running hydrogen and deuterium with Pd suggests heat generation when D is used, but minimally-so when H is used, supporting the view presented herein that deuterons are the major active component in these reactions. The minor activity in the hydrogen cells could be attributed to the 160 ppm presence of D in H.



Case cell Studies:
H₂ and D₂ Gas
with Pd/C Catalyst

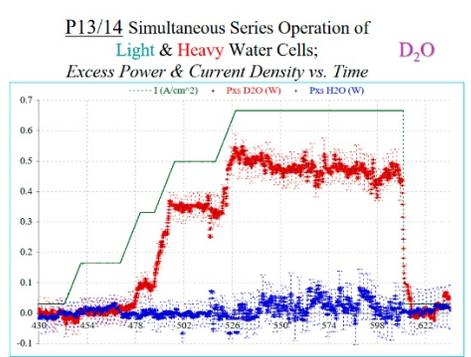
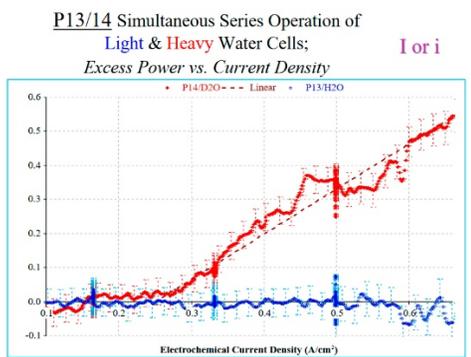
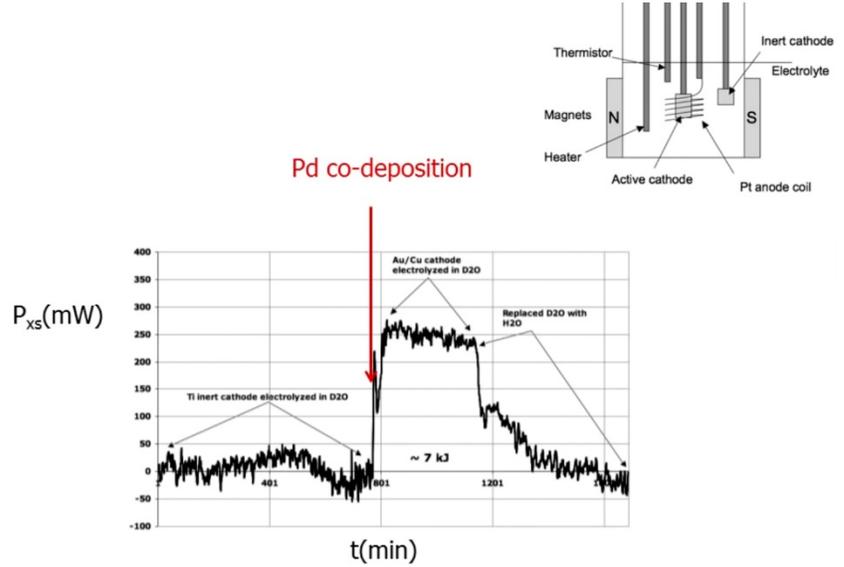


Figure 51. Simultaneous operation of deuterium-palladium and hydrogen-palladium cells at SRI International (Stanford Research Institute) by McKubre [38].



D Letts and P L Hagelstein, J. Cond. Mat. Nucl. Sci. 6 44 (2012)

Figure 52. Substitution of D₂O by H₂O stops heat generation.

COMMENTARY ON CMNS EXPERIMENTS

Peter Hagelstein from MIT, comments on other Condensed Matter Nuclear Science (CMNS) experiments:

"We have experiments confirming the basic effect, we have experiments showing that energy is produced, that the energetic reaction products are not there, and the question is what to do about it. Actually, we should be very interested in these experiments. We should be interested, because we have experimental results which by now have been confirmed a great number of times. We learned about nature from doing experiments. So, here are experimental results. Can we, should we pay attention to them? Follow them up, see, where they lead? Today, sadly, the experiments in the cold fusion business are not considered to be part of science. And that is the resolution that we have come to as the scientific community. From my perspective, having been in labs, having seen the results, having talked to experimentalists, having looked at the data, having spent great time on it, it looks like pretty much these experiments are real. They need to be taken seriously."

The lack of convincing reproducibility, commercial vested interests, competing patent filings wars, lack of credibility and personal biases deteriorated into civil court legal proceedings, disputes on licensing, controversial litigation and even suspect unauthorized technology transfer to foreign entities. A maze of financial, industrial and commercial interests including Leonardo Corporation, Hydro Fusion, Woodford Investment Management, Johnson Matthey (JM) from the UK expanding its horizon from precious metals into sustainability technologies, and private company Industrial Heat LLC of North Carolina, USA, which "generates electricity from centralized power plants from renewable energy resources" and entrepreneurial private equity/venture capital firms such as Cherokee Limited Partners of North Carolina, USA, IPH International B. V. and their "predecessors" and "affiliates", with armies of lawyers, patent attorneys, paid consultants and their own engineers and scientists, are involved in a competition for turf, territory and financial interests. For instance: "IHHI became the sole owner of IH, through stock swaps," "Cherokee has raised over \$2.2 billion in five institutional private equity funds, and invested this capital in the acquisition, cleanup, development, and sale of approximately 550 environmentally contaminated real estate assets in the US, Europe and Canada." "With the Settlement Agreement, (IHHI) may write this off entirely, producing tax benefits for shareholders, as they have pass-through profit and loss."

The price of Palladium, used as a catalyst in the automobile industry, has significantly increased to higher than the price of platinum as well as gold, implying possible accumulation and hoarding by some informed well-heeled financial interests. Demand is so high that there are reports, in the USA and UK of thieves stealing catalytic converters, sometimes in broad daylight, to extract the precious metals Pt and Pd used as catalysts. Pd is following the tracks of Li and the rare earths Nd and Gd as the elements of new innovative technologies.

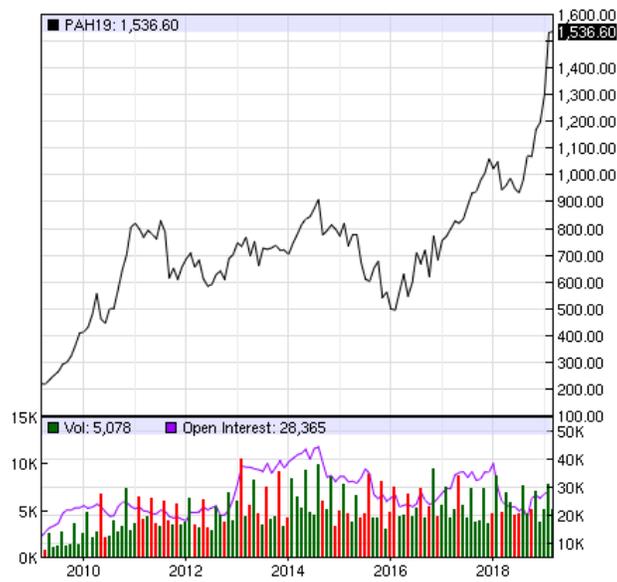


Figure 53. Rising price of Pd over 10 years from \$200/oz to \$1,530/oz by a factor of $1530 / 200 = 7.65$ times = 765 percent , with decreased volume and open interest implying possible accumulation and hoarding. Source: Nasdaq.com.

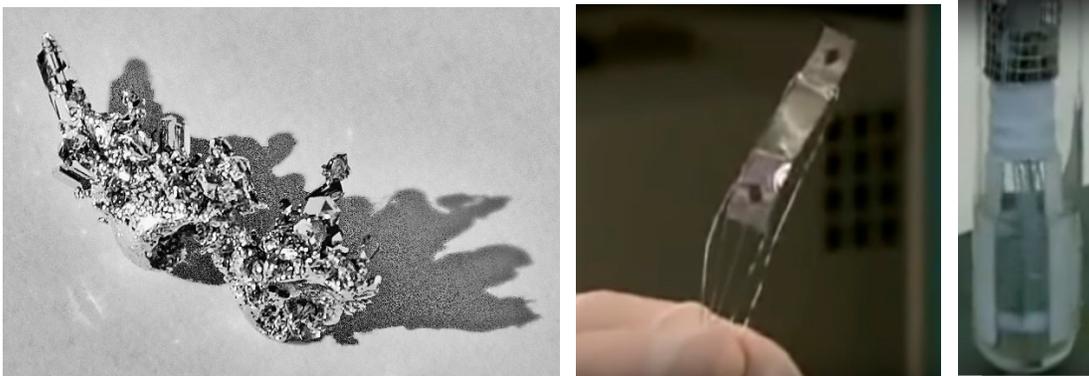


Figure 54. Palladium metal has become more valuable than gold and platinum. Pd cathode in D_2O cell at SRI International (Stanford Research Institute), San Diego, CA, USA.



Figure 55. Deuterated Pd nanoparticles powder. Source: Peter Hagelstein and Mitchell Swartz, MIT.

The lack of commercialization of the Ni/H devices since their inception and their different incarnations leads vocal critics to express doubts about the devices as viable consumer or industrial products. Major parts of this kind of device were “worn” after a year of operation, which led to a reconsideration of commercialization. The saga continues as a plasma-based process which “produces a lot of light, heat and some electricity at a claimed high Coefficient of Performance COP (>10)” has resurrected the old Ni/H devices’ designs into a third incarnation involving corona discharges.

THE NEED FOR ASSYMETRY AND A FLOW SYSTEM

Historically, liquid fuels have substituted for solid fuels. Solid coal as a fuel for steam boilers, for instance, was replaced with liquid petroleum once it was discovered. It may be suggested that once understood, a significant breakthrough in the postulated processes may occur when a *flow system* with a slurry, liquid or gaseous reactants interacting with the solid reactants would supersede the used stationary solid reactants, providing reliable continuous, rather than pulsed operation.

Some principles of energy conversion apply to specific cases in engineering and practical science, while still falling under the universal umbrella of the Laws of Thermodynamics. A first basic principle of energy conversion or extraction from the environment can be simply enunciated as:

“Energy can only be extracted from a flow system.”

A corollary is that:

“The energy flow is from a high energy storage reservoir to a low energy sink.”

In hydroelectric power generation, the potential energy of water blocked behind a dam, a waterfall or a dam on a river or stream cannot be extracted unless it is allowed to flow. In this case only a part of it can be extracted by a water turbine.

In a heat engine, the heat energy cannot be extracted from a totally insulated reservoir. Only when it is allowed to flow from a high temperature reservoir at which heat is added, to a low temperature reservoir where it is rejected to the environment, can a

fraction of this energy be extracted by a heat engine.

In geothermal energy production the differential temperature deep underground close to the magma and the Earth surface allows for an energy flow producing steam to drive a steam turbine.

In Ocean Thermal Energy production (OTEC) the cooler temperature deep in the ocean compared with the warmer temperature at the surface allows for the boiling of a low boiling-point working substance such as ammonia (NH_3) at the surface and then its condensation at the cooler depth resulting in a flow system. Ocean tidal power generation depends on the flow of water stored at a period of high tide behind a dam to flow out of storage at a period of low tide. Ocean wave production uses the difference in the kinetic energy content in waves from crest to bottom generated by wind flow on the surface of the water.

Totally blocking a wind stream does not allow efficient energy extraction. Only by allowing the wind stream to flow from a high speed region to a low speed region can energy be extracted by a wind energy converter.

A second principle can be stated as:

“Only asymmetries in a hydraulic, kinetic, thermodynamic or aerodynamic system allow the extraction of a portion of the available energy in the system.”

Ingenious devices, conceptualized by ingenious people, take advantage of naturally existing asymmetries. Alternatively, ingenious artificial configurations or situations favoring the creation of these asymmetries are created so as to extract energy from the environment.

A third principle is that:

“The existence of a flow system necessitates that only a fraction of the available energy can be extracted at an efficiency characteristic of the energy extraction process, with the rest returned back to the environment.”

A corollary ensues that:

“The conversion efficiency is proportional to the width of the existing natural or the created artificial asymmetry.”

In thermodynamics, the ideal heat cycle efficiency is expressed by the Carnot cycle efficiency. In a wind stream, the ideal aerodynamic cycle efficiency is expressed by Betz's efficiency equation.

DISCUSSION

The benefits of Condensed Matter Nuclear Science (CMNS), if understood, achievable and reproducible, would be obvious: a non-carbon, green, safe, and abundant energy source. Unfortunately, consistent reproducibility of the experimental setups remains elusive.



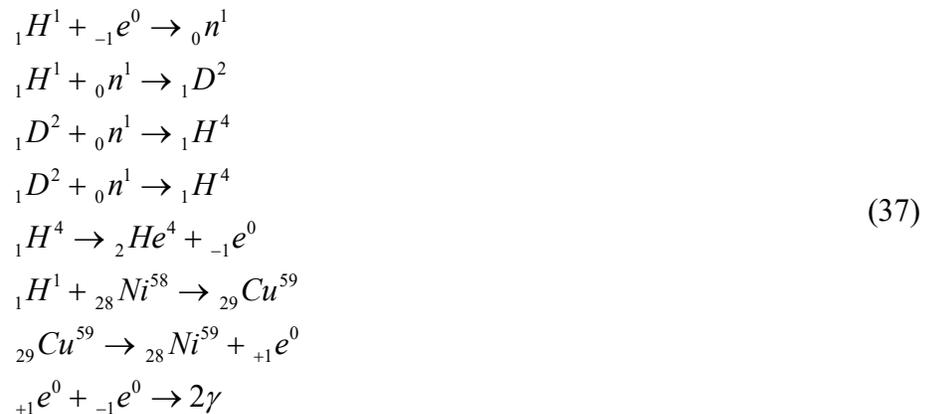
Figure 56. Light bulb invention by Thomas Edison. New York Times, January 16, 1880: “... after a few more flashes in the pan, we shall hear very little more of Edison or his electric lamp, Every claim he makes has been tested and proved impracticable.”

Fleishmann and Pons and Jones [1, 2] managed initially to get bursts of heat in one out of eight electrolytic cells in 1989. They increased the reproducibility in the 1990s, but the field was then no longer part of mainstream science.

One ponders the comment in Scientific American, January 2nd, 1909: “That the automobile has practically reached the limit of its development is suggested by the fact that during the past year no improvements of a radical nature have been introduced.”

A condition to be met was found that at least 92 percent loading of deuterium in Palladium is required to have any hope of seeing heat bursts. The trials at Caltech, MIT and other laboratories in 1989 were nowhere close to that 92 percent criterion.

The process of Deuteron disintegration and the Oppenheimer-Phillips process observed in the laboratory as well as in Nature in the Oklo Phenomenon has been abandoned in favor of using a model based on cheaper but complex and debatable hydrogen and Nickel interactions:



The second equation occurs in H₂O-moderated PWR AND BWR nuclear power plants with the neutron cross section of hydrogen being 0.332 barns. The third equation occurs only in D₂O moderated reactors (CANDU). The tritium generated by fission reactors largely comes from spallation of the boron added as a chemical shim, and as a direct tertiary fission-fragment.

Other theoretical frameworks were attempted to explain Condensed Matter Nuclear Science (CMNS) processes. Peter Hagelstein at MIT proposed in 1989 as a model the "Spin-Boson oscillator theory":

“Molecular D₂ and nuclear lattice-based He⁴ form two-level systems that contain large transition energy. They become coupled with other D₂-He⁴ systems via resonant phonon excitations (aka low-energy harmonic oscillators) throughout the lattice (aka Spin-Boson Model). Phonon modes are initiated by flux through the near-surface of the cathode. Increased phonon excitation and energy transfer rate is achieved by reduction of interference augmented through a "loss process". This rapid, distributed, small energy quanta exchange is what allows for D-D fusion to occur at lattice sites without correlated radiative effects.”

Another advanced far-fetched model is the Widom Larsen theory which proposes that:

“‘Heavy electrons’ formed at the surface of palladium hydride react with a proton in the palladium nucleus in an inverse beta decay process (e⁻ + p⁺ -> n + neutrino). The required electron mass enhancement is proposed to be the result of very high electromagnetic fields produced by surface plasmon polariton resonance. The neutron produced would have "ultra-low momentum," and thus very high capture cross-section. These neutrons can then cause transmutation and energy release.”

Table 4. Comparison of fission and CMNS reactions.

	Operational Temperature °C	Power density Wth/cm ³	Power flux Wth/cm ²	Volume cm ³
Fission fuel pellet	300	180	32	1.0
Electrolysis cathode	100	300	16	0.3

Two panels convened by the USA Department of Energy, one in 1989 and a second in 2004, did not recommend a dedicated federal program for Condensed Matter Nuclear Science (CMNS) research. Nevertheless a limited number of researchers continue working on the field, particularly in Japan (Toyota, Mitsubishi), Italy, China and the USA. For instance, Mitchell Swartz used preloaded nanocomposite ZrO₂-PdNiD producing Condensed Matter Nuclear Science (CMNS) based excess heat in an open demonstration at MIT in 2012.

Demonstration projects were initiated at MIT, the University of Missouri, and the University of Bologna. Public presentations were done by executives at the National Instruments Company designed to attract the top Condensed Matter Nuclear Science (CMNS) researchers into a project to test and quantify observed Condensed Matter Nuclear

Science (CMNS) effects. A report was issued in July 2012 by the European Commission's research and development center suggests that Condensed Matter Nuclear Science (CMNS) has a sustainable future energy technology potential.

NASA apparently filed two Condensed Matter Nuclear Science (CMNS)-related patents in 2011 after a leading NASA scientist indicated that LENR is real enough to pay attention to, and study. The Boeing Company and NASA may even have conceptualized aircraft using Condensed Matter Nuclear Science (CMNS) or other similar concepts.

The new field called “Condensed Matter Nuclear Science, CMNS” with a subfield being “Low Energy Nuclear Reactions, LENRs” is not pseudoscience. Real experimental work is being done globally, by experienced, knowledgeable and talented curious researchers and scientists, for exploration to develop hypotheses and to test them, and even real physicists are working on possible theory. Claims of impossibility cannot be proven, because logic suggests that: “Absence of evidence is not evidence of absence.” And evidence is encountered in many cases.

The great romantic expectations about CMNS as it is presently understood concerning the hopeful absence of radiation and waste products appear to be overstated and exaggerated. Nuclear reactions from D as a neutron donor to other nuclei will be associated with neutron-rich nuclei which try to reach stability primarily by beta emission from the resulting nuclei. Beta emissions in turn are associated with gamma rays emission from the nuclei and from x-rays resulting from the electrons' bremsstrahlung process.

There is even a chemical hazard associated with the hydrogen generated as it is highly reactive with oxygen in the air. The residual transmuted nuclei could be themselves stable or radioactive depending on the associated decay chains. Researchers are ethically and professionally obligated to adopt serious radiation health physics protection measures for themselves and their associates when engaged in experimentation, development and ultimate operation.

Commercial application of CMNS and LENR technology may eventually be successful, but it could take a very long time, much like other technologies including conventional DT and DD magnetic and inertial confinement fusion. LENR is a real phenomenon, but difficult to control, due to severe problems with material conditions, and its full theoretical understanding still evolving.

In summary, detractors, skeptics and naysayers suggest that the marketplace will eventually decide the viability of the multiple discussed approaches and concepts, even though plasma hot fusion is still trying hard to produce a practical power reactor using magnetic and inertial confinement, despite 60 years of research and over \$100 billion in government funding; yet no one questions the existence of plasma fusion for that reason.

Advocates point out that countless other natural phenomena have no practical application, but are not disputed. They respond that there are and always have been countless unexplained phenomena which are unquestionably real such as black holes, black matter and dark energy in cosmology, and feel that it is the job of science to explain anomalies rather than to dismiss them. If we humbly know only about 5 percent of the known universe, the good news is we have a motivation to explore the remaining 95 percent.



Figure 57. Black holes at the centers of the galaxies, black matter and dark energy remain as topics for exploration and discovery.

Table 5. Postulated composition of the universe.

Universe components	Percentage
Black matter keeps galaxies from gravitationally dislocate.	25
Dark energy as poorly understood invisible property of space accelerating the expansion of the universe.	70
Normal matter as protons, planets, stars and galaxies.	4.9

As a sobering but realistic assessment, CMNS is real but it has its own analogue of the Lawson criterion. It will become mainstream when the following “breakeven condition” is realized:

$$\frac{\text{Number of advocates}}{\text{Number of detractors}} \geq 1$$

The fact is that: “Proof is evidence that is so strong it would be statistically unreasonable to deny it.” Proof in science occurs through repeated replications and trials, not through single experiments. Only then, and if convincingly demonstrated, its brave dedicated pioneers would be receiving their well-deserved recognition by their children, and not posthumously from their grandchildren.

APPENDIX

ZENO OF ELEA ACHILLES AND TORTOISE ASYMPTOTIC PARADOX

Around 450 BCE, the Greek philosopher Zeno of Elea advocated the idea that Achilles was unable to catch a tortoise. This is often called “Zeno’s Paradox”; it is only one of several attributed to him.

Achilles can run ten times faster than the tortoise, which is given a head start of 100 m. They both begin running at the same time. How far must Achilles run to exactly catch up to the tortoise?

After 100 m, when Achilles reaches the tortoise’s starting point, he sees that it is now 10 m farther ahead. When Achilles reaches the 110 m mark, the tortoise has gained

another 1 m. Each time that Achilles reaches the place where the tortoise had been, it still is 10 percent farther ahead. Zeno's "paradox" is that the swift Achilles cannot catch the slow-moving tortoise.

Not really: Achilles eventually catches the tortoise.

Assuming a constant speed V , the distance travelled by Achilles over a time period t is:

$$D_{Achilles} = V \times t$$

The tortoise runs at one tenths the speed of Achilles and is given a 100 m lead, so the location of the tortoise is:

$$D_{Tortoise} = 100 + \left(\frac{V}{10} \times t \right)$$

Achilles catches the tortoise when:

$$D_{Achilles} = D_{Tortoise}$$

$$V \times t = 100 + \left(\frac{V}{10} \times t \right)$$

$$V \times t - \left(\frac{V}{10} \times t \right) = 100$$

Assuming Achilles speed to be $V = 1$ m/sec, the time elapsed will be:

$$1 \times t - \left(\frac{1}{10} \times t \right) = 100$$

$$t \times \left(1 - \frac{1}{10} \right) = t \times \left(\frac{9}{10} \right) = 100$$

$$t = \frac{1,000}{9} \text{ sec}$$

Thus Achilles catches the tortoise after travelling a distance:

$$D_{Achilles} = V \times t$$

$$= 1 \times \frac{1,000}{9} \text{ m}$$

$$= 111.111 \text{ m}$$

The tortoise would have travelled a distance of:

$$\begin{aligned}\frac{V}{10} \times t &= \frac{1}{10} \times \frac{1,000}{9} \\ &= \frac{100}{9} \\ &= 11.111 \text{ m}\end{aligned}$$

The power of Modern Algebra was not available at Zeno's time, but it became available much later in time by Islamic Culture mathematician Abu Jaafar Mohammed Ibn Musa Al-Khwarizmi who lived in Baghdad, around 780 - 850 AD. He was a scholar at the "House of Wisdom" in Baghdad; a group of scholars interested in re-engaging with the brilliant work of the ancient Greeks, which had been lost and almost forgotten for centuries. They were involved in translating the classic Greek texts, and they published their own research on algebra, geometry, medicine, philosophy and astronomy. They helped bridge the gap between the Dark Ages and the Renaissance periods in Europe.

Around 825 AD mathematician Abu Jaafar Mohammed Ibn Musa Al-Khwarizmi wrote the book "Hisab (Calculation) Al-Jabr (of Completion) Wal-Muqabala (and Balancing)", from which we inherited the word "Algebra", meaning 'restoration of broken parts'. Al-Khwarizmi helped establish widespread use of the Arabic/Indian numerals in replacement of the Roman numerals. He was also instrumental in encouraging the use of the number "0" or "null" as a place holder. From the name Al-Khwarizmi, we also inherited the word: "Algorithm".

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