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CONTENTS FOR DECEMBER 1990

COMING IN JANUARY 1991

Fusion Facts will name its annual "FUSION SCIENTISTS OF THE YEAR."

FEATURE ARTICLE: "Fusion Year, 1990, in Review." by *Fusion Facts* Staff.

A. PONS ON VACATION & NCFI REVIEW

Contrary to media reports, Professors Fleischmann and Pons have not disappeared nor "run off". Professor Pons and his family had planned a vacation in France. After waiting several weeks for a meeting of the Governor's committee on Energy and Cold Fusion, Pons and family left on vacation. Pons also requested a sabbatical from the University of Utah to devote more time to furthering cold fusion research. Having two homes in Utah, Dr. Pons reportedly put one of them up for sale, and had the phone disconnected.

The result: a media report that Pons had disappeared. Actually, those who have an official need to contact him can do so by simply calling his attorney.

Professor Pons was contacted when the energy committee meeting was finally called. He interrupted his vacation, returned for a meeting of the energy committee and made his report. Later, Dr. Pons also attended the scientific review meeting at the National Cold Fusion Institute.

Meanwhile Professor Fleischmann was vacationing at his home in England, where he was interviewed on national television -- after the news media tried valiantly to interpret his absence as running away from the cold fusion research. Truth is much less popular than speculation.

NCFI SCIENTIFIC REVIEW

Dr. Fritz Will, Director of the National Cold Fusion Institute, University of Utah Research Park, invited four distinguished scientists to participate in a scientific review of the cold fusion research efforts at NCFI. The review was held November 7, 1990. The report will be presented to the members of Utah's Energy and Cold Fusion Committee at its December 20, 1990 meeting.

The four reviewing scientists are:
Dr. Robert K. Adair, Physics, Yale.
Dr. Stanley Bruchenstein, Chem., St U of NY, Buffalo.
Dr. Loren G. Hepler, Chem., U. of Alberta, Canada.
Dr. Dale F. Stein, President, Michigan Tech U.

See the Jan '91 issue of *Fusion Facts* for a report.

B. HAPPY HOLIDAZE & FUSION NEW YEAR

By Hal Fox

And now some stories in my fractured rhyme
To enlighten your mind at Christmas time.
So settle down and unloose your sashes
While we raise cold fusion from its dead ashes [1].

Theory is improving and it oughta.
Whose is the best? "Mine." says Preparata [2].
Bush and Chubb say "Mine has something to it" [3,4].
And Hagelstein says, "Give mine what's due it" [5].

Get excess energy out of those jars?
That's as likely says Jones as hopping to Mars [6].
"Commercial?, No way!" he may rave and rant.
But Jones is happy with his DoE grant [7].

In Morrisonland, round hot fusion fire
Nuclear physicists sit and conspire.
Fusion without neutrons is bad logic.
We shall proclaim it to be pathologic [8].

Random House gives thirty thousand to start
And says now go tear cold fusion apart.
So down at TAM they found tritium and like it.
In comes Taubes and proclaims that they spike it [9].

These wizards advising the government
Direct how DoE money is spent.
Now you taxpayers: don't suffer delusion
That five hundred million goes to hot fusion.

If only Watkins [10], Sununu [11], and Bush
Knew about cold fusion they wouldn't rush
To have our troops in an Arab muddle,
Just to recover Kuwait's oil puddle.

N. Lewis, et al. when they reported
Negative results - cold fusion aborted [12].
But in their data, Noninski has found
Unreported excess heat did abound [13].

Noninski wrote where Lewis did publish,
But scolded *Nature*, "That must be rubbish" [14].
Truth is undaunted, reality soars --
But cold fusion in nature, *Nature* abhors.

Yamaguchi on Pd plated gold;
Also O and Mn, thus, so he told --
He loads with D_2, then sucks it away.
A million neutrons were measured that day [15].

Liebert and Liaw's invention: they tried
Molten salts with palladium inside [16].

Great interest to cold fusion they've sent:
Excess heat at fifteen hundred percent.

It's true that some have their head in the sand
But don't you get trapped in Morrisonland [8].
So here is a fond wish to fill your socks:
"Cold fusion is real!" by *Nature's* Maddox [17].

REFERENCES:

[1] National television interview with President of Am Physical Society, March 1990 citing the Salt Lake Cold Fusion Conference as being the last gasp of a dead corpse.

[2] Giuliano Preparata (Dipt. di Fisica, U. di Milano, Italy), "Theoretical Ideas on Cold Fusion", *The First Annual Conference on Cold Fusion, Conference Proceedings,* University Park Hotel, SLC, UT, March 28-31, 1990, pp 91-98.

[3] Robert T. Bush (Cal State Poly Tech.), "Isotopic Mass Shifts in Cathodically-Driven Palladium via Neutron Transfer suggested by a Transmission Resonance Model to explicate enhanced Fusion Phenomena (Hot and Cold) within a Deuterated Matrix", *The First Annual Conference on Cold Fusion - Conference Proceedings*, March 28-31, 1990, University of Utah Research Park, Salt Lake City, Utah, pp 213-227.

[4] S.R. Chubb & T.A. Chubb (Research Systems, Inc.), "Lattice Induced Nuclear Chemistry", *Proceeding of Anomalous Nuclear Effects in Deuterium/Solid Systems,* [in press], Brigham Young University, October 22-24, 1990. [See also review in *Fusion Facts*, Vol 2 No 5, Nov 1990, pp 30-32.]

[5] Dr. Peter L. Hagelstein (MIT), "Status Report on Coherent Fusion Theory", *The First Annual Conference on Cold Fusion - Conference Proceedings,* March 28-31, 1990, University of Utah Research Park, Salt Lake City, Ut., pp 99-118.

[6] *Deseret News*, Published interview in which Prof. Jones states that getting commercial energy from his type of cold fusion as likely as a grasshopper hopping to Mars.

[7] *Fusion Facts*, Vol 1, No 8, Feb 1990, p 1: Dr. Gajewski reported he had funds for cold fusion. He was replaced in his job. However, Prof. Jones (BYU) got a $600,000 grant to study geologic cold fusion.

[8] D.R.O. Morrison (CERN), "Review of Cold Fusion", *Special Symposium Proceedings -- Cold Fusion*, World Hydrogen Energy Conf. #8, Honolulu, HI, July 23-24, 1990, p 233.

[9] M.H. Hecht, "Who's Trying to Spike Cold Fusion?", *Fusion Facts*, Vol 2, No 1, p 16, July 1990.

[10] Personal communication. Letter answered by staff member.

[11] Personal communication. Sununu wrote, "I shall review the FACTS as they come in!", Feb 5, 1990.

[12] N.S. Lewis, et al., *Nature*, Vol 340, pg 525ff (1989).

[13] V.C. Noninski, "Observation of Excess Energy is the Essence of Fleischmann-Pons Effect", *Fusion Facts*, Vol 1, No. 12, p 20, June 1990.

[14] Personal communication with *Nature* Washington staff. Quote is poetic license.

[15] E. Yamaguchi & T. Nishioka, "Cold Nuclear Fusion Induced by Controlled Out-Diffusion of Deuterons in Palladium", *Japanese Journal of Applied Physics, Part 2 Letters*, Vol 29, No 4, pp L666-L669.

[16] Bor Yann Liaw, Peng-long Tao, Patrick Turner, Bruce E. Liebert (U. of Hawaii), "Elevated Temperature Excess Heat Production Using Molten Salt Electrochemical Techniques", *Special Symposium Proceedings - Cold Fusion*, World Hydrogen Energy Conference #8, p 49-60, July 23-24, 1990, Honolulu, Hawaii. [See also *Fusion Facts*, Vol 2 No 4, Oct 1990, pages 1-14 for a reprint and an extensive review of all references.]

[17] Poetic license, or technological forecast.

C. HUGGINS ON ELECTRODES.

Robert A. Huggins (Stanford), "Fundamental Considerations Relating to the Electrochemical Insertion of Hydrogen and Palladium into Mixed Conductors," *Proceedings of the World Hydrogen Energy Conference #8, Cold Fusion Symposium*, July 22-27, 1990, pp 181-213.

ABSTRACT

A number of features of the presence of interstitial species in metals and alloys relevant to recent experiments related to the "cold fusion" issue are discussed. These include experimental evidence for very high virtual pressures under certain conditions, and the influence of promoters and surface blockers. Dislocation generation and motion results from the large stresses accompanying composition gradients and phase transformations. Because of preferential segregation of interstitial species to dislocations, dislocation motion can cause unusually rapid solute transport and emission from surfaces. Mechanical effects related to hydrogen insertion often are sporadic and can have long delay times. It is possible that some of the same microstructural features and phenomena that are responsible for delayed mechanical behavior play an important role in the "cold fusion" observations.

EDITOR'S COMMENTS

In the paper by Dr. Robert Huggins (Stanford U), various factors leading to spatial and temporal variations within samples, and factors leading to a dependence of the sample behavior on its history and on minor impurities, are discussed. It is suggested that such factors could easily give rise to effects which are both poorly reproducible and sporadic (i.e. with the unpredictable time dependence often observed for cold fusion episodes, due not to the cold fusion mechanism but to a natural outgrowth of the conditions under which a microstructure dependent reaction takes place.)

The rich scientific literature dealing with the hydrogen, deuterium and tritium uptake and diffusion in palladium and other metals was also noted (including the 82 selected references cited in this paper). An additional important study was presented by Dr. Storms at the Anomalous Nuclear Effects conference at BYU, and is reported in the October 1990 issue of *Fusion Facts*. It was mentioned that palladium has been studied the most extensively because of the rapidity of its hydrogen uptake, and that papers on electrolytic loading of Pd with H date back to the 1860's. It was indicated that extensive studies have been performed in recent decades because of interest in hydrogen storage in metals and hydrogen batteries, as well as failure of metals due to hydrogen embrittlement or stress corrosion cracking. Hydrogen embrittlement is one of the factors which has been implicated in the splitting or breakage of electrodes reported in some cold fusion electrolysis experiments. Uneven loading due to oxide films may be another factor.

An extensive discussion was given of how catalysis of the dissociation of species such as H_2 or D_2 by the surface of a metal like Pd can lead to conditions similar to those which would exist if the metal were exposed to a gas pressure many orders of magnitude higher than is actually the case, and how electrolysis can also give rise to such effects. In time, given the high diffusion rates of H or D in Pd, not only the surface layers but also the interior will behave as though they were exposed to high pressures of these gases.

It was pointed out that large stresses accompanying the expansion of metal lattices during hydrogen uptake result in the formation of very large numbers of dislocations in the lattice (especially at grain boundaries), and eventually in phase transitions and plastic deformation or cracks. Considerably higher local deuterium concentrations may be expected next to dislocations (especially at low temperatures). It was pointed out that particularly high stresses and deformation may occur as loading of Pd with H or D increases to the point at which separation of the hydride or deuteride into alpha and beta phases (with quite different hydrogen or deuterium contents, and a striking 9% volume difference) abruptly occurs.

It was also pointed out that erratic behavior may result from the fact that the alpha-beta phase transition is typically not simultaneous throughout the alloy, but may involve partially coherent nucleation of the alpha phase at the surface and its growth in dendritic platelike features. It has also been shown that the time of onset of the phase transition is variable, and that the degree of coherence of the transition can vary depending on the source of the Pd, apparently in part as a result of minor impurities. (In certain other metals, similar transitions which are partially or fully coherent are also possible under appropriate conditions). In addition, it was noted that repeated cycles of phase transitions lead to smaller and smaller grains. Thus even an electrode initially consisting of a single Pd crystal, as has been recommended by some researchers, would not ordinarily be expected to remain a single crystal for long.

Data on alpha Pd hydride/deuteride samples, showing an increase in the hydrogen or deuterium solubility in Pd of up to 63% in the most highly deformed cold-rolled samples over that in annealed samples, was cited to indicate the large effect which dislocations can have. Huggins stated that this effect explains why hydrogen-deuterium solubility in annealed samples is often found to be quite similar regardless of the annealing method, while a large amount of scatter and higher solubility values have been reported in experiments on deformed samples. The increase in solubility with defect concentration was said to account for the increase in hydrogen uptake during cyclic alpha-beta phase transitions. Enhancement of cold fusion has in fact occasionally been suggested in some experiments after samples have been loaded and unloaded a few times. The concentration of hydrogen isotopes at dislocations may also have resulted in the very non-uniform tritium distributions reported in a number of experiments such as those performed at BARC in India [Iyengar et al., *Fusion Technology* 18(1), August 1990].

Prior deformation of Pd, resulting in defect formation, was also said to decrease the diffusion rates of hydrogen isotopes (including both deuterium and tritium) as much as several-fold, in part because the dislocations can act as traps for the hydrogen. On the other hand, migration of defects during deformation is expected to increase hydrogen movement; hydrogen is in effect carried along (at strain rates below a certain maximum value). For instance, in experiments in which tritium was used as a tracer, tritium evolution was shown to increase up to several fold during plastic deformation, with the increase related to the deformation rate, and fracturing and (in some cases) phase transitions can have a similar effect. Thus, even if tritium is generated at a steady rate in a cold fusion experiment, the rate at which it is released into the solution may show abrupt spikes.

Finally, surface conditions may have a major impact on hydrogen uptake. For example, it has long been known that the presence of even very small amounts of a variety of promoters (listed as P, As, Sb, Bi, Se, Te, CN, I and certain organic and sulfur compounds) can greatly increase hydrogen uptake by metals, both from a gas phase and under electrolysis. (For example, about a 10-fold enhancement in a steel was shown at an arsenic concentration of 1 part per million.) It was pointed out that data is lacking on the influence of promoters under electrolytic conditions in many cold fusion experiments.

On the other hand, unlike the case in metals such as Pd which are resistant to oxidation at room temperature, hydrogen uptake in non-noble metals is typically greatly impeded by the formation of oxide films on the metal surface. Even in the case of Pd, it has been suggested that minor surface oxides may be responsible for variability in the onset of phase transitions.

A situation with analogous irreproducibility was cited: Large variations in the time required for different samples of a metal exposed to hydrogen to fail as a result of processes such as hydrogen embrittlement and stress corrosion cracking may occur, and large changes may also result due to prior sample history.

Related presentations have also been made by Drs. Storms and Talcott at the Anomalous Nuclear Events conference at BYU (reported in the November issue of *Fusion Facts*) and by Coupland et al. at the First Annual Conference on Cold Fusion. For instance, Coupland et al. observed that after deposition of Li in the surface layer of a Pd electrode by electrolysis in a Li-containing solution, the electrode absorbed hydrogen more readily than a similar rod electrolyzed in Na- or K-containing solutions. Coupland et al. also reported that wide differences in properties of different Pd rods were found when their hydrogen absorption and desorption were measured by temperature cycling.

D. COLD FUSION IN NATURE

FOLLOWING FIVE ARTICLES ARE FROM B.Y.U. WORKSHOP ON ANOMALOUS NUCLEAR EFFECTS IN DEUTERIUM/SOLID SYSTEMS. Oct. 1990.

TRITIUM & ^{3}He IN MASSACHUSETTS

Peter Britten (The Riess Foundation), "Preliminary Data from the Hamilton Shear Zone Project", *Proceedings of Anomalous Nuclear Effects in Deuterium/Solid Systems Conference*, Brigham Young University, October 22-24, 1990.

ABSTRACT

Over the past ten years the Riess Foundation at its Totten Field Laboratory in South Hamilton, Massachusetts has conducted deep drilling and scientific studies to better understand the dynamics of potable water production in fractured crystalline rock. Geochemical studies have produced some tritium and helium-3 measurements which may relate to low temperature fusion processes.

Three wells of depths of 1400-6000 feet have been drilled in a northwest trending shear zone in crystalline rocks of the Salem-Gabbrodiorite complex. All rocks but especially the rhyolite and diabase dikes have been subject to intense shearing and hydrothermal alteration and deposition of distinctive carbonates in all cracks and microcracks. Measurement of gases in solution in well T2 (1870 ft) taken from samples obtained at various depths indicates tritium and helium-3 concentrations increasing with depth. Subsequent measurement of head space gases from cores and gases released by acid treatment of the

same cores from well T3 also indicate elevated helium-3 concentrations and methane isotopes with similar values to East Pacific Rise basalts. The methane if considered a tracer suggests deep-seated origins for the helium-3.

One of the objectives of our research has been to understand the dynamics of a low temperature/high pressure hydrothermal system as it relates to potable water production. The Hamilton shear zone is of interest due to high water yields, in excess of 300 gpm, as well as its location as part of a large transverse fault system expressing itself as part of the White Mountains and the New England Seamount Chain. This zone is seismically active and crosscuts an older subduction zone.

Gas concentrations, isotopic ratios, and rock porosity support the position that production of helium-3 and tritium is ongoing in the shear zone. The linear increases in concentration of both these gases suggest a single source or process involving both these gases. Current research is examining the carbonate filled microcracks to better understand if there are pathways through which these gases migrate. It is conceivable that a vestigial hydrothermal system continues to be activated by a heat source related to either a leaky transform fault, the ancient subduction zone beneath the Boston area, or a translated hotspot related to the New England Seamount Chain.

Signatures for low temperature fusion effects hopefully can be derived from our current data sets and future research.

TRITIUM IN VOLCANOES

Fraser Goff, Jamie N. Gardner, William Crisswell (Earth and Environmental Sciences Division, LANL), Lisa Shevenell (Water Resources Center, Desert Research Institute, Reno), H. Gote Ostlund (Tritium Laboratory, U of Miami), and Mike Colucci (Stable Isotope Laboratory, Southern Methodist Univ, Texas), "The Tritium Content of 'Magmatic' Water Emitted from the Post-1980 Lava Dome, Mount St. Helens Volcano, Washington", *Proceedings of Anomalous Nuclear Effects In Deuterium/Solid Systems*, Brigham Young University, October 22-24, 1990.

ABSTRACT

Tritium, deuterium, oxygen-18, and chemistry were determined on six samples of condensed steam from 118 to 265 C fumaroles on the lava dome within Mount St. Helens crater. Gas analyses show the fumaroles contain 14 to 90% air. Steam condensates were collected from stainless steel tubes buried in the throats of fumaroles. These tubes were connected to glass condensers immersed in a dry ice/ethanol slush. A hand pump was used to slowly suck fumarole vapors through the condensing system to trap all water. Tritium values of the six condensates range between 4.33 ± 0.14 and 4.55 ± 0.15 TU (1 TU = 3.237 pCi/kg H_2O). Previous results of an earlier stable isotope investigation of the dome fumaroles,
hot springs, cold waters, and rocks indicate that the fumarole steam is a mixture of meteoric water precipitated in the crater and magmatic water produced during open-system degassing of silicic melt. The tritium data verify that significant meteoric water is cycled through the fractured lava dome. To estimate the value of magmatic tritium, tritium values of the condensates are plotted versus their delta^{18}O values and the resulting trend is extrapolated to the delta^{18}O content of St. Helens magmatic water (5.94 ppm; Evans, 1981). The value of magmatic tritium obtained by this method is about 3 TU. Anomalous tritium is not produced by reaction of fumarole gases with stainless steel nor is significant tritium contributed from air cycled through the dome. At this time it is not possible for us to evaluate the cause of the apparent value of 3 TU. Although cold nuclear fusion is a provocative explanation, other scenarios that involve assimilation of relatively high tritium, post-bomb water into the magma conduit beneath the dome can explain the anomalous magmatic value.

TRITIUM IN VOLCANOES

Gary M. McMurtry (U of Hawaii) and Steven E. Jones (Brigham Young U), "Investigations of Tritium in Hotspot Volcanic Emissions as Evidence of Natural Cold Fusion Reactions in the Earth", *Proceedings of Anomalous Nuclear Effects In Deuterium/Solid Systems*, Brigham Young University, October 22-24, 1990.

ABSTRACT

Recent laboratory experimental observations of cold nuclear fusion in condensed matter have suggested that similar nuclear reactions may occur in the interiors of planets such as Jupiter and the Earth. Observations of excess ^{3}He, an important fusion reaction product, have been recorded in volcanic emissions and rocks at various active plate tectonic settings. In particular, hotspot volcanoes, which tap deeper portions of the mantle than mid-ocean ridge or island arc volcanoes, emit the largest amounts of excess ^{3}He. To date, the most widely held explanation for this excess is the primordial nature of the mantle plumes which supply the upwelling magmas.

An alternate explanation for this ^{3}He excess, at least in part, is cold nuclear fusion in the Earth's mantle and/or core. Tritium (T), another important fusion reaction product, is a short-lived radioisotope ($t_{1/2}$ = 12.43 years)

that decays by beta emission to ^{3}He. In principle, unequivocal detection of tritium in volcanic emissions would, unlike ^{3}He, prove that cold nuclear fusion is occurring in the Earth's interior.

There is some evidence that anomalous environmental tritium has resulted from an eruption of Kilauea volcano. A tritium-monitoring station was operated at Mauna Loa volcano on Hawaii island from August 1971 to the end of 1977. A striking spike in the tritium level is clearly seen in the February-March 1972 Mauna Loa data (consisting of six 48-hour collection means). The timing and shape of the peak is inconsistent with hydrogen bomb tests in Russia five months earlier but this signal is coincident with a major eruption of Mauna Ulu volcano, located on the upper East Rift Zone of Kilauea 40 km to the southeast. Furthermore, winds in March 1972 carried volcanic gases northwest, towards the Mauna Loa station and on towards Honolulu 200 km away.

Based on the distance to the Mauna Loa station and average 8 mph winds, we estimate that an average 100 curies of tritium was released per day for 30 days. This estimate is probably a minimum value, since no anomalous tritium was detected in the water component, suggesting that any HTO in equilibrium with the atmospheric HT probably condensed and separated from the rising hot volcanic gases prior to arrival at Mauna Loa. An accidental release of this magnitude of man-made tritium sustained for several weeks is highly unlikely. The Mauna Ulu volcanic eruption may have freed tritium produced by geological nuclear reactions, but tritium released from bomb-contaminated groundwater aquifers when dike intrusions of the emerging volcano "burned" into the upper East Rift Zone could account for the anomalous tritium signal.

To date, our search for a volcanic tritium signal has focused on the active submarine hotspot volcanoes Loihi Seamount, located off the Island of Hawaii, and Macdonald Seamount, located at the southern terminus of the Austral Island Chain. Macdonald Seamount is one of the most active submarine volcanos in the world. The shallow (to 40 m water depth) eruptive summit of Macdonald Seamount contributes large amounts of magmatic gases, Fe, Mn and Si-rich hydrothermal fluids, and sulphur and sulphide-rich pyroclastic debris to the surrounding seawater, producing water column anomalies quite different from other hotspot or mid-ocean ridge hydrothermal activity. In November 1989, we sampled the water column over Macdonald during a seismically inactive period. Although large amounts of CO_2 and methane degassing were detected, there were no significant enrichments of HTO above the levels commonly found within the upper 400 m of the ocean.

The summit of Loihi Seamount contains several active hydrothermal vent fields at water depths of about 1000 m and greater. Since the HTO contamination background rapidly decreases to <0.1 TU (1 TU = approximately 7.1 dpm/kg) below 400 m in the equatorial Pacific, any signal found in the vent fluids above the detection limit could represent unequivocal evidence for geological nuclear reactions. Tritium levels of two samples collected from low-temperature (10-30° C) hydrothermal vents by a manned submersible in March 1990 are low but positive at 0.09 ± 0.05 TU, as was the level of a control sample taken near the vents at 0.08 ± 0.07 TU. In order to better constrain these data, more precise tritium measurements will need to be conducted, as well as HT measurements of the hydrogen component of these gas-rich hydrothermal fluids. [Kilauea and Loihi are suspected of tapping a magma source at an unusually great depth in the mantle, thus they are good sites to test for tritium produced in the earth's mantle. Ed.]

FUSION IN THE EARTH

E. Paul Palmer (Brigham Young U), "Cold Nuclear Fusion In The Earth", *Proceedings of Anomalous Nuclear Effects In Deuterium/Solid Systems Conference*, Brigham Young University, October 22-24, 1990.

ABSTRACT

The search for hydrogen-isotope fusion catalyzed in solid matter was first suggested by tentative evidence that such fusion occurs in the earth. It was reasoned that some catalytic action by earth materials might be occurring to produce effects similar to those produced by cold, muon-catalyzed fusion. In muon-catalyzed fusion, the heavy muon binds the hydrogen atoms in a molecule close together and the atoms fuse quickly giving the products ^{3}He for P-D fusion or ^{3}He + n or T + P for D-D fusion. Geologic evidence suggestive of catalyzed, hydrogen-isotope fusion includes effects associated with heat, with fusion products, and the negative evidence of too little radioactivity. Such evidences are: (1) The atmospheric concentration of fusion product ^{3}He is high (considering its escape velocity) unless there is an active or primordial source. (2) A high ratio ^{3}He/^{4}He is associated with volcanic gases, liquids, and lavas. (3) Tritium, a fusion product with half-life of 12.4 years, is associated with volcanic gases and hot-spring waters. (4) The heat of the volcanism associated with subducting, cold, water-bearing sedimentary rock appears to be too high to be explained solely by frictional heat generated from gravitational potential energy and heat from surrounding rock. (5) Conventional U/Th/K radioactivity is not associated with the hot spots of the earth but is prominent in the cold continents; fusion products are found in the hot spots.

(6) The ability of U/Th/K radioactivity to supply the excess heat balance of the earth or to produce the high core temperature is in doubt. Relating these geologic evidences to the results of laboratory-produced cold fusion, suggests that fusion should not be ignored as a possible source of earth energy and isotopes. Fusion rates need only be 10^{-30} of those of muon-catalyzed fusion to be of interest. This paper will include discussions of the geologic evidences for fusion, the comparison of laboratory- and geology- derived fusion rate constants, and tentative evidences of fusion in earth-like materials in the laboratory.

ASTROPHYSICAL FUSION

M. Gajda and J. Rafelski (U of AZ), "Astrophysical Limits on Low Energy Fusion", *Proceedings of Anomalous Nuclear Effects In Deuterium/Solid Systems Conference*, Brigham Young University, October 22-24, 1990.

ABSTRACT

We investigate limits on cold fusion following from the existence of the giant planets which are not stars as well as the consequences which cold fusion (if it exists) would have on a history and internal structure of such planets. Our analysis is patterned at the standard model of Jupiter structure and conventional wisdom about low energy nuclear reactions. We do not account here for any exotic mechanisms which have been considered in the search for theoretical explanation of cold fusion neutrons and we do not go beyond the scope of conventional physics.

The existing theories of the Jupiter are constrained by the observational properties of this planet. The major conclusions of modern models of Jupiter are: the planet consists of a fully mixed core of fluid metal and is in convective equilibrium, electron gas is degenerate, central density is 4 g/cm^3 and central temperature is about 125,000 K. Both these quantities change very slowly inside Jupiter, up to its radius R= 7.15 x 10^9 cm. In particular well known in the cold fusion community is the fact that Jupiter radiates about twice as much energy as it receives from the Sun. The questions we ask are:

1) If this energy excess were to originate from cold fusion, would the fusion rate be easily observable in laboratory?

2) Assuming the d-d fusion rate reported by Jones' et al., how big a fraction of the energy radiated by Jupiter can cold fusion provide?

In Figs. 1,2 the radial distribution of the computed number of p-d and d-d fusions per unit time is presented. The difference (about 9 orders of magnitude) is due to enhanced tunneling of p-d as well as much smaller density of deuterons. We determine that the energy production rates by p-d, p-p and d-d fusions are negligible fractions of the observed luminosity of Jupiter, even though, as we see from the figures, even according to conventional wisdom p-d fusions indeed occur quite frequently inside Jupiter! On the other hand, if all excess heat of Jupiter were to originate from d-d nuclear burning by a yet not determined mechanism, this would require a fusion efficiency of sigma times v = 10^{-37} cm^3/sec which would be about nine orders of magnitude greater than seen by Jones et al. Work supported by the US-DOE/BES-AEP.

EDITOR'S COMMENTS

This presentation by Dr. Gajda indicated that neither cold fusion at the Jones rate nor conventional fusion would yield detectable increases in the measured heat output from Jupiter.

It is noted that even though Jupiter is potentially well suited for cold fusion, except for its primordial D/H ratio of 10^{-5}, fusion at the Jones rate would produce 9 orders of magnitude less energy than the 7 x 10^{24} ergs/second of excess energy radiated by Jupiter; thus observed cold fusion rates are not inconsistent with such astrophysical evidence.

Calculations of conventional thermonuclear fusion rates expected within Jupiter were also made; in spite of the fact that Jupiter is just below the point at which thermonuclear fusion should ignite, calculations of the amount of energy which would be generated were approximately 17 orders of magnitude less than the excess energy radiated. (These calculations used standard assumptions, such as Gamow exponentials, Debye-Huckel screened potentials, and Debye-Thomas-Fermi screening radii, taking into account enhancement due to correlations with neighboring particles resulting from the high pressure, and assuming a Maxwell-Boltzmann distribution.)

ADDITIONAL CONFERENCE REFERENCES

The following list contains: 1. selected additional references cited by BYU conference presenters; 2. references to related papers previously published or presented; and 3. references to several papers published since the BYU conference (and reviewed elsewhere in this issue as indicated).

BITTNER:

* M. Bittner et al., "Method for Investigation of Fusion Reactions in Condensed Matter," *Fusion Technology* 18(1), August 1990, pp 120-130

BRUDANIN:

* V.B. Brudanin et al., "Does Cold Nuclear Fusion Exist?," *Physics Letters A* 146(6), June 1990

* V.B. Brudanin et al., "Once More About Cold Fusion," *Physics Letters A* 146(6), June 1990, pp 351-6

BUSH:
* Robert T. Bush, "Isotopic Mass Shifts in Cathodically-Driven Palladium Via Neutron Transfer Suggested by a Transmission Resonance Model to Explicate Enhanced Fusion Phenomena (Hot and Cold) Within a Deuterated Matrix," presented at the First Annual Conference on Cold Fusion, Salt Lake City UT, March 28-31, 1990
* Robert T. Bush, "Cold 'Fusion': the Transmission Resonance Model Fits Data on Excess Heat, Predicts Optimal 'Trigger' Points, and Suggests Nuclear Reaction Scenarios," presented at the World Hydrogen Energy Conference #8, Cold Fusion Symposium, July 23-24, 1990
CECIL:
* F. Cecil et al., "Study of Energetic Charged Particles From Thin Deuterated Palladium Foils Subject to High Current Densities," presented at the Workshop on Cold Fusion Phenomena, Santa Fe NM, May 23-25, 1989
CHAMBERS:
* George Chambers et al., "An Investigation of Cold Fusion in Thin Titanium Films", presented at the First Annual Conference on Cold Fusion, Salt Lake City UT, March 28-31, 1990
CHUBB:
* S.R. Chubb and T.A. Chubb, "Bloch-Symmetric Fusion in PdD_x," *Fusion Technology* 17(4), July 1990, pp 710-2
* S.R. Chubb and T.A. Chubb, "Quantum Mechanics of 'Cold' and "Not-So-Cold' Fusion," presented at the First Annual Conference on Cold Fusion, Salt Lake City UT, March 28-31, 1990
CZIRR:
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E. MORE NEWS FROM THE U.S.

BROOKHAVEN - CLUSTER IMPACT

R.J. Beuhler, Y.Y. Chu, G. Friedlander, L. Friedman and W. Kunmann (Brookhaven National Laboratory), "Deuteron-Deuteron Fusion by Impact of Heavy Water Clusters on Deuterated Surfaces," *J. Phys. Chem* 94, 1990, pp 7665-7671.

ABSTRACT

The apparatus and techniques for producing, accelerating, and measuring beams of 200-325 KeV singly charged cluster ions containing up to hundreds of D_2O molecules are described. The diagnostics used to ascertain beam quality via secondary electron distributions are discussed. Results on DD fusion obtained when $(C_2D_4)_n$, TiD, and $ZrD_{1.65}$ targets are bombarded with D_2O cluster ions are presented, including the dependence of fusion rates on target, beam energy, and cluster size. DD fusion events are also reported for H_2O clusters impinging on $(C_2D_4)_n$, but the rate is only 5% of that found with D_2O clusters of the same size and energy. Extensive tests performed to exclude artifacts as the cause of the observed DD fusions are described and discussed.

EDITOR'S COMMENTS

Fusion Facts apologizes for not having had the opportunity to review this second article on experimentally determined cluster-impact "warm" fusion rates before the Anomalous Nuclear Effects conference in October, as Dr. Cerefolini and Dr. Kim discussed possible interpretations of the data from both studies. Also, note that a similar experiment has also been performed using D_2 by Fallavier et al. (*Phys. Rev. Lett.* 65, 1990, p 621).

By accelerating singly ionized clusters of hundreds of D_2O molecules, it was noted to be possible to generate beams containing a greater density of molecules than is possible if each molecule or atom in the beam is ionized, and the energy per molecule is also far lower. A sample calculation showed that a cluster of 100 atoms accelerated to 10^7 cm/sec (10^5 eV total energy, or 1000 eV per D_2O) would impact a 10^{-14} cm^2 size area of the target in roughly 10^{-14} second, equivalent to 10^{30} particles/cm^2/sec or 10^{11} A/cm^2. The energy deposited in this example would be 10^{16} W/cm^2, and if the cluster is stopped in 10 atomic layers of the target, the energy per target atom would be near 100 eV. This was noted to be equivalent to the typical deuteron kinetic energy at 10^6 K, sufficient for some thermonuclear fusion involving the deuteriums to be expected [R. Beuhler and L. Friedman, *Chem. Rev.* 86, 1986, pp 521-537].

In the ion source, He gas saturated with approximately 2% D_2O was weakly ionized in a corona discharge; cluster ions were formed in a controllable fashion during expansion of the plasma through a supersonic nozzle and extracted. Passage of the gas through a mass spectrometer then both established the approximate distribution of cluster sizes and screened out low molecular weight ions. The clusters were then accelerated toward the target by an electrical field. A Si solid-state charged particle detector was used to detect 3-MeV protons, 1-MeV tritons, and [0.82 MeV] ^{3}He from such d-d fusion. Several types of auxiliary experiments were also performed to indicate that the observed fusions were not due to impurities in the beam (i.e. small ions which would possess much higher kinetic energy per deuterium if accelerated by the same electrical field as a large cluster). Beam intensities and beam current measurement techniques were significantly improved over earlier experiments [R.J. Beuhler, G. Friedlander and L. Friedman, *Phys. Rev. Lett.* 63, 1989, pp 1292-5]. In addition, ^{3}He detection has now allowed direct measurement of the branching ratio between the d+d-->t+p and d+d-->n+^{3}He reactions, which is very close to 1 for thermonuclear fusion but has been measured to be 10^{7-9} in a variety of cold fusion experiments. (In the previous Brookhaven experiment, the ^{3}He peak had been obscured by X-rays accompanying the impact.)

The experiment detected unexpectedly high fusion rates for clusters with mean sizes ranging from 20 to 1300 D_2O molecules, with maximum rates of 8 per 10^{10} cluster impacts (0.05 fusions/sec/cluster nanoampere) for clusters of approximately 200 molecules on deuterated polyethylene, $(C_2D_4)_n$, at approximately 300 KeV. Rates were several times lower for clusters larger than 500 or smaller than 100 molecules. Yields for Ti and Zr deuteride targets were only approximately half that for polyethylene targets, although the polyethylene (with up to 10% excess carbon) contained only 40% more deuterium than TiD; the remainder of the discrepancy was attributed to the greater stopping power of the polyethylene. Rates at 150 KeV were approximately 1 to 1-1/2 orders of magnitude lower than at 300 KeV. The (tritium+proton) / (neutron+^{3}He) branching ratio was estimated to be 1.2 ± 0.2 under these warm fusion conditions.

Taking the area of the cluster impact as 10^{-14} cm^2, the penetration depth as 10^{-7} cm, and the time as 10^{-13} second, the fusion rates were on the order of 5 x 10^{-20}/cm^3/sec, which would be that expected for deuterons with 2-KeV center-of-mass energies. Thus, while the clusters initially consist of approximately 0.3 KeV D atoms and 2.4 KeV O atoms, the clusters behaved as though a significant fraction of the deuterons acquired kinetic energies in excess of several KeV during the collision.

Beuhler et al. note the paper by Echenique et al. (*Phys. Rev. Lett.* 64, 1990, p 1413), which suggests that the fusion rate is due to the small number of deuterium atoms in the high-energy tail of the Maxwell-Boltzmann velocity distribution. (Since the cross-section increases very rapidly with energy, being nearly 1000 times greater at center-of-mass energies of 4 KeV than at 2 KeV, rare higher-energy deuterons can have a marked effect even if the average deuteron energy is low.)

Although the branching ratio measured is the same as for thermonuclear fusion, it is interesting to note other unusual behavior in this experiment besides the unexpectedly high fusion rate noted. First, the fusion rate in H-on-D impacts was 20 times lower than the rate for D-on-D, while H-D fusion rates much greater than D-D rates have previously been predicted at such low energies. Second, the rate dropped much more slowly at lower energies than in conventional thermonuclear fusion. Third, the dependence of the rate on cluster size was unusual. The data of Fallavier et al. is also intriguing. It will be interesting to see more such sub-KeV data in the future.

MISSOURI - THEORETICAL ASPECTS

Peter H. Handel (U. of Missouri), "Intermittency, Irreproducibility, and the Main Physical Effects in Cold Fusion," *Fusion Technology* 18(3), November 1990, p 512.

ABSTRACT

Heterogeneous nucleation of D_2 bubbles at the surface of the cathode is suggested as the cause of difficulties encountered in the reproduction of electrolytic cold fusion experiments. In some experiments, active nucleation centers are present only intermittently leading to a temporary increase in the chemical potential of deuterium in the cathode up to the homogeneous nucleation limit, which is approximately 1.2 eV higher. The increased effective mass of electrons, expressed in the electronic specific heat and in the De Haas Van Alphen effect, is considered as a possible cause of cold nuclear fusion, along with the stronger heavy fermion effects directly observed at low temperatures, but localizability of these states remains a problem. Breakdown of the charge invariance of internucleonic forces at very low center-of-mass energies of the order of 1 eV applicable to this form of (non-mu-mesonic) cold fusion, leads to preferential tunneling of neutrons into nearby deuterons, which is suggested as an explanation for the conspicuous absence of neutrons and ^{3}He.

EDITOR'S COMMENTS

Several theoretical aspects of cold fusion are covered; a similar presentation by Dr. Handel was also given in October at the Anomalous Nuclear Effects conference at Brigham Young University (reported in the November 1990 issue of *Fusion Facts*).

The first section of this paper suggests that poor reproducibility and sporadicity in electrolysis experiments may be partly related to the ease with which D_2 bubble formation occurs. It was pointed out that in the absence of nucleation centers, supersaturations of 40% or more may be attainable before homogeneous nucleation finally leads to D_2 bubble formation, compared with only 1-3% supersaturation under normal conditions. The resulting greater deuterium activity within the metal when deuterium loss through bubble formation is postponed may be a necessary condition for appreciable fusion to occur. A quantitative treatment of the effect of homogeneous nucleation was presented which showed that the increased deuterium activity in the electrode was equivalent to that which would be produced by a deuterium gas pressure of 10^{20} atm.

Thus, it was suggested that impurities and defects which can act as nucleation centers should be minimized. Unfortunately, it has been pointed out in other papers, such as that of Dr. Huggins at the World Hydrogen Energy Conference #8, reported in this issue, that formation of hydrides or deuterides results in very large numbers of defects, so that defects exposed at the electrode surface could be expected even if a single crystal of pure Pd is initially used.

Also, it was indicated the electrode should be kept fully submerged, that a strongly hydrogen-rejecting metal (as listed below) be used in making the connection to the electrode, and that all such connections and leads be insulated to ensure that only the electrode is in contact with the electrolyte. In addition, in order to maximize the degree of supersaturation which can result before homogeneous nucleation takes place, it was indicated that the surface tension of the electrolyte should be kept high. It was also noted that periods of homogeneous nucleation, and thus higher deuterium activity in the cathode, would be marked by an increased voltage drop at the cathode surface.

Note that Dr. Handel's article would suggest the design of Dr. Taniguchi's charged particle/electrolysis experiment (*Japan J. of Appl. Physics*, 28(11), pp L2021-3) may yield low loading ratios due to exposure of the lower surface of the Pd foil electrode to a vacuum. An extremely thin layer, such as that of Yamaguchi (*Japan J. Appl. Physics Letters*, 29(4), pp L666-9) may be helpful in this case.

Strongly hydrogen-rejecting metals were listed as Cr, Ni, Cu, Ag, Au, Mo, W, Co, Mg, Cd, Zn, and Al. Deuterium absorbing metals were listed as Sc, Y, La, Ti, Zr, Hf, V, Nb, Ta, Pd, and rare earths such as Er, Te and Lu. It was noted that hydrogen isotope absorption is greatest at low temperatures in hydrogen-absorbing metals, while in hydrogen-rejecting metals it is greatest at high temperatures. Diffusion rates in hydrogen-absorbing metals were noted to increase exponentially with temperature, and also to decrease with increased loading.

The second section of the paper deals with the increased electronic effective masses in hydrogen (deuterium) absorbing metals. While the thermal effective mass of the electrons seen in specific heat measurements on hydrogen-rejecting metals such as Pd is comparable to that of free electrons, the effective mass measured in metals such as Pd which take up large amounts of hydrogen is several times larger, and that in some heavy fermion compounds is up to 1000 times larger. This was attributed to a collective lattice effect, and suggested to both help bring deuterons closer together (in cases in which two deuterons occasionally and temporarily occupy the same lattice position, under conditions of high loading and deuteron motion), and help transfer the energy of the reaction to the lattice through multiphonon emission. (In comparison, the mass of the muon is 207 times that of the electron.) However, it was noted the heavy fermion states are prevented from catalyzing fusions in the same fashion as a muon because they are not localized.

Examples of heavy fermion compounds which were listed were $CeAl_3$, $CeCu_2Si_2$, $CeCu_6$, UBe_{13}, UPt_3, UCd_{11}, U_2Zn_{17}, $CePb_3$, and $CeSn_3$; it was suggested that some of these could be promising alternatives to Pd and Ti. It should be noted that surface oxide films in such non-noble compounds in electrolysis experiments will inhibit hydrogen uptake unless experiments are carried out in a suitable environment such as that of the molten-salt cell used by Liebert et al..

The third section of the paper discusses a possible mechanism involving deuteron polarization (orientation of the neutron-proton pairs in two deuterons closely approaching one another). This approach would favor the d + d --> n + ^{3}He reaction over the d + d --> t + p reaction much more strongly than the Oppenheimer-Phillips model, thus providing an explanation of the extremely low neutron/tritium branching ratio in d-d fusion.

ROCHESTER - SCREENING THEORY

Jacob Jorne (U. of Rochester), "Electrochemically Induced Nuclear Fusion of Deuterium: the Existence of Negatively Charged Deuteride Ions," *Fusion Technology* 18(3), November 1990, pp 519-522.

ABSTRACT

Cold fusion of deuterium by electrolysis of heavy water onto a palladium (or titanium) cathode has been reported. Contrary to the assumption of Fleischmann and Pons that electrochemically compressed D^+ exists inside the palladium cathode, the observations of Jones et al. can be partially explained by the simultaneous presence of deuteride D^- and the highly mobile positive deuterium ion D^+. The opposite charges reduce the intranuclear distance and enhance the tunneling fusion rate. Furthermore, alloying of lithium with palladium can stabilize a negatively charged deuteride ion due to the salinelike nature of lithium deuteride. The enormous pressure (or fugacity), achieved by the applied electrochemical potential (10^{30} atm), is a virtual pressure that would have existed in equilibrium with palladium deuteride (PdD_x). It is speculated that nuclear fusion occurs at the surface, and the PdD_x serves as a reservoir for the supply of deuteride ions.

EDITOR'S COMMENTS

This paper proposes an alternative explanation for how greatly increased screening of the Coulomb repulsion between deuteriu ms in Pd can occur, which also suggests why prolonged electrol-ysis and the presence of lithium in the electrolyte could be important.

Existing models and experimental evidence for the presence of D^- as well as D^+ in Pd deuteride are discussed. For example, it is suggested that a predominant D^- form could account for the amount of

lattice expansion which occurs on loading of Pd with D and other characteristics of PdD_x, while smaller amounts of D^+, due to their much higher mobility, could account for the electrochemical behavior (migration of deuterium to the cathode during electrolysis). It is suggested that alloying of Li with the Pd during lengthy electrolysis could aid in the creation of D^+, since LiD_x is ionic in nature, with the deuterium present as D^-. It is also suggested that the other alkali and alkaline earth metal ions in the electrolyte used by Dr. Jones could possibly also play such a role. Although not indicated in the paper, the discussion of the role of Li would suggest that a Pd-Li alloy might permit bulk rather than merely surface reactions. Also, the paper does not address the possibility of unusual neutron/tritium branching ratios.

ROCKWELL & OTHERS - ATTEMPT TO MEASURE He

John R. Morrey (Pacific Northwest Laboratories), Mark W. Caffee (Lawrence Livermore National Laboratory), Harry Farrar IV, Nathan Hoffman (Rockwell International), G. Bryant Hudson (Lawrence Livermore), Russell H. Jones (Pacific Northwest), Mark D. Kurz (Woods Hole Oceanographic Institution), John Lupton (U. of California- Santa Barbara), Brian M. Oliver (Rockwell), Brian V. Ruiz (Lawrence Livermore), John F. Wacker (Pacific Northwest) and A. van Veen (Delft U. of Technology, Delft, The Netherlands), "Measurements of Helium in Electrolyzed Palladium," *Fusion Technology* 18(4), December 1990, pp 659-668.

ABSTRACT

The results of a double-blind, cold fusion experiment are reported, in which six laboratories measured the helium content of five identically shaped 2-mm-diam x 10-cm-long palladium rods supplied by Fleischmann and Pons. Three rods were initially implanted with ^4He. Before analysis, three of the rods had served as cathodes during electrolysis in cold fusion experiments: two in 0.1 M LiOD, and one in 0.1 M LiOH. The other two, one implanted and one not, served as references. The major observations are as follows:

1. All the materials, including the as-received palladium stock, contained easily measurable quantities of ^4He, well above amounts normally found in high-purity palladium.

2. The ^4He could be totally removed from at least two of the materials, including the as-received palladium stock, by surface etching the samples to a depth of approximately 25 microns.

3. Helium implanted by alpha-particle bombardment remained in the electrodes throughout the electrolysis.

4. No ^3He was measured above detection limits in any of the materials by any of the six laboratories.

It cannot be proven that the minimal excess heating in one of the rods reported by Fleischmann and Pons can be attributed to the formation of ^4He, although the possibility that some ^4He could have formed during electrolysis cannot be ruled out. If ^4He were generated, the mechanism must be surface related, not bulk related. No attempt was made to measure any helium or tritium that might have left the cathode surface as gas during the electrolysis. The results presented cannot, unfortunately, confirm the existence or nonexistence of cold fusion via helium production. However, they provide a basis for follow-on experiments that should lead to a final conclusion.

EDITOR'S COMMENTS

As several of the proposed cold fusion reactions involve the production of ^4He, and as excess heat reported in some electrolysis experiments has greatly exceeded that which can be accounted for by the conventional neutron-and tritium-producing d-d fusion reactions, careful experiments such as this could provide valuable independent evidence for a nuclear reaction and valuable guidance for theorists. As reported by Dr. Hoffman at the Anomalous Nuclear Effects conference at Brigham Young U. on October 24, 1990, a subsequent experiment did measure ^4He levels in one of four segments of the heat-producing Pd electrode in the Liaw, Liebert et al. molten-salts experiment which were 14 standard deviations above background. (See the November 1990 issue of *Fusion Facts* for more details.) It is unfortunate that unusually high background ^4He levels in the surfaces of the rods and low excess heat generation in the electrodes from the Fleischmann-Pons group prevented a similar answer in the present experiment, but it is hoped that similar analyses will continue to be carried out in the future according to the criteria outlined at the end of this discussion. The double-blind design and replication by different leading outside laboratories should also aid in confidence-building if used again in the future. Finally, analyses designed to also distinguish between surface and bulk ^4He production would also be of particular interest both to theorists and experimentalists.

The analyses described were coordinated by Pacific Northwest Laboratories (Richland, Washington) at the request of the U. of Utah. The rods (99.8% Pd) were originally obtained from the Johnson-Matthey Technology Centre (Blount's Court, Sonning Common, Reading RG49NH, England) under their Loans Scheme. The Pd rods were melt refined by Johnson-Matthey from Pd sponge in an induction furnace in a $10\%H_2/90\%N_2$ atmosphere, then cast into square bars, hot forged at 1000

C in air, cold rolled, and finally drawn into round bars. The surface 1.2 microns of three rods were implanted by Johnson-Matthey with 3 x 10^{-7} moles of ^{4}He (10^{-6} moles/cm^3), using 500 KeV He ions in a vacuum. One of the implanted rods was electrolyzed in H_2O; one implanted and one unimplanted rod were electrolyzed in D_2O; the remaining implanted rod and unimplanted rod were not electrolyzed. (Electrolysis was carried out at 800 mA/cm^2 for 28 days.) Excess heat generation in one of the unimplanted rods was measured during the electrolysis, but was several orders of magnitude less than anticipated, amounting to only 5-8 mW (0.1% excess) over 24.3 days.

Each laboratory analyzed one 1 cm long segment from each rod. The samples were typically outgassed at a few hundred degrees to remove most of the D_2 (which has nearly the same mass as ^{4}He, and would thus interfere the most with mass spectrometry), then melted or vaporized to liberate trapped helium. The gas released was then exposed to various agents to remove most species other than helium, and analyzed in a mass spectrometer. The paper gives the full details of each laboratory's procedures.

In addition, various other analyses were performed: Pacific Northwestern also analyzed the electrolyte of the cell reported to have generated excess heat, but did not find elevated tritium levels. Rockwell used scanning electron microscopy to make sure that surface dendrites, which could have been lost on handling because of their fragile nature, did not appear to be present, and measured contaminants in the surface of the rods (which were normally negligible). Delft U. tested for tritium in the deuterium gas first evolved during heating, estimated the D/Pd loading ratio, and measured helium desorption as a function of temperature. (Maximum helium outgassing was observed in some cases at two different temperatures, approximately 600-725 and 1300 C, with release continuing up to 1600 C, in a pattern which depended strongly on the sample history; it was suggested that the lower-temperature outgassing may be due to helium in defects or cracks, with the higher-temperature outgassing due to helium in bubbles.)

The as-received rod contained an unexpectedly high ^{4}He content on the order of 10^{-10} to $10^{-10.5}$ moles/cm^3, although the source of the helium is not obvious and much lower values have been found in analyses of other samples from Johnson-Matthey and other suppliers. The rod for which excess heat was reported contained approximately an order of magnitude more ^{4}He, but this level was still 1-1/2 orders of magnitude less than would account for the excess heat reported. No helium production above the instrumental detection limit was found in the interior of the rod.

It was found by Rockwell that the ^{4}He in the as-received rods could be almost totally removed by surface etching, and found by Delft that electropolishing was similarly effective. The ^{4}He levels measured in the two implanted and electrolyzed rods agreed well with the amount expected to have been implanted, although the content in the implanted rod which was not electrolyzed was below the anticipated level, for undetermined reasons. Sample inhomogeneity was noted to give rise to large variations (10-50%) between different samples of the same rod; this was at least partially attributed to differences between surface and bulk ^{4}He levels (which it was suggested could differ by 10 orders of magnitude, from an inferred 10^{-2} moles/cm^3 at the surface of the implanted rods to less than 10^{-12} moles/cm^3 at depths greater than 25 microns, according to tests by Rockwell). It was also noted that the strong depth variations and agreement of implantation amounts and measured levels in two of the three implanted rods confirmed the expectation that helium migration at room temperature is minimal.

Detection limits for ^{3}He (3-8 x 10^{-13} moles/cm^3, or 2-5 x 10^{11} atoms/cm^3) were 8-9 orders of magnitude lower than the amount expected if the excess heat reported had been due to conventional d-d fusion. In addition, since ^{3}He would have also formed due to decay of a fraction of any tritium in the electrode during the 10-30 days before analysis, 5 to 7 orders of magnitude less tritium is also indicated than would account for the excess heat by conventional d-d fusion. Given these factors, if the excess heat measurements are correct, conventional d-d fusion would not appear to have been the source.

The researchers suggest that future tests concentrate on electrodes which have generated particularly significant total amounts of excess heat, and which have also previously been shown to contain very low levels of helium before electrolysis. (Recall that etching or electropolishing of the electrodes in the present experiment before use would have considerably improved detection levels, as even the lowest helium content measured was 40 times the detection limit of the Rockwell laboratory, 8 x 10^{-13} moles/cm^3.) The researchers also suggest analyses establish the distribution of helium with depth, and possibly an accompanying profile of the elemental composition (such as Li content).

TEXAS A&M - TRITIUM IN ELECTRODES

J.O'M. Bockris, letter to the editor, *Fusion Technology* 18(3), November 1990, p 523.

The letter by Dr. Bockris responds to recent questions regarding tritium measurements in electrolysis experiments at Texas A&M. In the experiment referred to, Dr. Kevin Wolf of Texas A&M reported the detection of

approximately 2000 dpm of tritium in recent analyses of 4 out of 20 Pd samples from Hoover & Strong (1 mm diameter x 5 mm rods, approximately one-tenth the normal electrode size). Dr. Bockris indicated that tests for trace contamination are a good practice, and indicated that samples in his laboratory have been analyzed for tritium contamination at Los Alamos National Laboratory.

In addition, Dr. Bockris noted three observations which should reduce concerns that this would diminish the integrity of other previous work. First, few of the 26 laboratories around the world which had reported tritium production in D_2O electrolysis experiments at the time of the letter had used palladium from this source, and in his opinion the idea that undetected tritium was inside the more commonly used Johnson-Matthey Pd was unacceptable. Second, Dr. Bockris noted that some researchers consider that the analyses may contain errors. Third, Dr. Bockris noted the difficulty in explaining how tritium contamination of Pd prepared by Hoover & Strong, which electrolytically deposit their noble metals one at a time from solution by gradually changing the voltage. As the difference in deposition potential between Pd and T is large, the probability of contamination should be minute. Furthermore, tritium should escape during subsequent melting of the Pd, regardless of the form it is in. Any tritium introduced during cooling of the Pd after this step should not be in a form which could survive for the reported 1-2 months of electrolysis.

(An internal investigation at Texas A&M has also indicated that tritium produced in the previous electrolysis experiments was not due to deliberate tampering.)

HYDROGEN UPTAKE BY INTERMETALLICS
(Courtesy of Dr. Samuel Faile)

W.E. Wallace, R.S. Wallace, R.S. Craig, & V.U.S. Rao, "Hydrogen Absorption by Intermetallic Compounds," in Solid State Chemistry: A Contemporary Overview (Advances in Chemistry Series No. 186), V 12, pp 207-240.

This reference and a previous report described in the July 1990 issue of *Fusion Facts* ("Intermetallic Compounds as Solvents for Hydrogen") available from Dr. Wallace, Mellon Institute Advanced Materials Corporation, 4400 Fifth Ave, Pittsburgh PA 15213] report on a variety of alloys which take up large quantities of hydrogen, such as Er-Fe-Mn, R-Ni, R-Co-Cr and Er-Zr-V alloys, where R is a rare earth element, La or Hf. For example, it is reported that a bulk specimen of $ErFe_2$ in a test absorbed 3.9 hydrogen atoms per Er in only 120 seconds at room temperature when exposed to H_2 gas at a pressure of 2.6 MPa, apparently without a phase transition, while a bulk specimen of a compound related to ZrV_2 (in which half of the V had been replaced by Er) disintegrated into a powder when it absorbed hydrogen. Note that these alloys, like Ti, are not noble metals; thus surface oxide films may be a problem in electrolytic cells.

G. NEWS FROM ABROAD

GERMANY - WARM FUSION PROPOSAL

Gunter Nimitz and Peter Marquardt, "A Proposal for a Lukewarm Nuclear Fusion," *Fusion Technology* 18(3), November 1990, p 518.

ABSTRACT

A nuclear fusion process in the dielectric medium of sub-micrometre metal particles is proposed that reduces the Coulomb repulsion forces. The process may allow nuclear fusion at a rather moderate "lukewarm" temperature of 10,000 K.

EDITOR'S COMMENTS

As an alternative to cold fusion, this paper suggests the testing of reactors using a porous network of minute metal particles, for which exceptionally high dielectric constants have been measured. For instance, bombardment of silver particles of diameters of roughly 10 nm (measured dielectric constant on the order of 10^5) with approximately 1-eV deuterons is proposed. This technology certainly seems interesting. However, the temperature suggested would be above the melting point of a metal. In addition, the branching ratio which would result from this mechanism was not discussed. A neutron/tritium ratio near unity would make such a reactor less appealing than a cold fusion cell in which a branching ratio of $10^{-7\text{-}9}$ could be achieved.

INDIA - HIGH TRITIUM IN TiD
(Courtesy of Dr. Subbiah Arunachalam, Editor, India J. of Technology)

T.C. Kaushik, A. Shyam, M. Srinivasan, R.K. Rout, L.V. Kulkarni, M.S.Krishnan, S.K. Malhotra and V.B. Nagvenkar (Bhabha Atomic Research Centre, India), "Preliminary Report on Direct Measurement of Tritium in Liquid Nitrogen Treated TiD_x Chips," *Indian Journal of Technology* 28, December 1990, pp 667-673.

ABSTRACT

In a simple experiment to look for anomalous nuclear phenomena widely known as "cold fusion," batches of hundreds of deuterated titanium (TiD_x) chips were directly

cooled in liquid nitrogen (LN_2) and warmed up to room temperature many times. The chemically cleaned chips were earlier deuterated using D_2 gas of known tritium content. During the first thermal cycle, a significant spike which may be attributed to a neutron burst, was registered in a bank of 10 BF_3 counters. The chips were later analysed for tritium by counting for tritium betas directly, possibly for the first time in such experiments, using a gas flow beta counter as well as indirectly by counting the beta excited Ti K X-rays using a NaI detector. A surprisingly high (approximately MBq) level of activity was detected in four chips besides significant amounts of tritium (> KBq) in more than 50% of the chips of a batch of more than a thousand TiD_x chips. However, some auxiliary experiments suggest that the low level (approximately KBq) tritium in a majority of the chips may possibly have resulted due to cross-contamination from the four high activity chips when cycled together in LN_2. No tritium activity was observed, within the detection thresholds (approximately 0.5 KBq) of the available detectors, in any of the remaining batches from the same stock even when some of them were similarly treated in LN_2. The results appear to be in conformity with similar experiments conducted at Frascati [Italy], Los Alamos, Trombay [BARC, India] and several other laboratories, where neutron bursts were reported from deuterated titanium when subjected to repeated thermal cycling by LN_2. The process responsible for the "anomalous generation" of MBq level of tritium activity in four out of the approximately thousand TiD_x chips remains to be investigated.

EDITOR'S COMMENTS

This experiment, which showed activity in four gas-loaded Ti chips out of a batch of approximately 1000, dramatically demonstrates the difficulties which can arise in attaining reproducibility. The tritium levels reported are also exceptionally high. This paper provides additional information beyond Dr. Srinivasan's presentation at the BYU conference (reported in the November 1990 issue of *Fusion Facts*). (A number of previous experiments of various types were described in the August 1990 issue of *Fusion Technology*; this experiment is more recent.)

The Ti chips (3-8 mg each, total about 10 grams) were prepared from Ti rods obtained from Mishru Dhatu Nigam Ltd, Hyderabad, India. Chips of 0.2-0.5 mm thickness, approximately 1 mm width and a few mm length, were obtained by machining one of these rods at low speed using a tungsten carbide tool under spray cooling by a mixture of kerosene and water, then breaking up these pieces further. The chips were treated with a 1:1:1 (volume basis) mixture of nitric acid, sulfuric acid and water for 10 minutes to remove the surface oxide layers, then washed with distilled water followed by acetone. Immediately prior to gas loading, the chips were treated with hydrochloric acid for 10 minutes, and again washed with distilled water and acetone.

The chamber containing the chips was evacuated to a pressure of 10^{-5} torr, heated to 850 C for 2 hours, and allowed to cool slowly to 600 C. At this point 1 bar of D_2 gas was introduced, and the chamber allowed to cool to room temperature. The tritium content of the D_2 gas used was estimated to be 10.84 Bq/ml (t/d ratio approximately 10^{-13}), as determined by exchange with D_2O and liquid scintillation counting. The average loading was estimated to be only D/Ti = 0.05, based on the drop in pressure in the chamber; however, because of the slow diffusion of deuterium in Ti, considerably higher loading near the surfaces of the chips was expected. After deuteration, the chips were cooled in liquid nitrogen, then allowed to warm to room temperature over about 10 minutes, and the cycling was repeated 4-5 times.

Neutron measurements were performed using a bank of BF_3 counters with paraffin moderator located in a circle around the chamber. The total efficiency was approximately 1%, and the background count rate was 5 counts/second. One possible burst of over 15 times background, corresponding to about 10^4 source neutrons, was recorded in a 5-second interval during the first liquid nitrogen cycling.

Tritium measurements were performed with a 2-pi gas flow counter using liquefied petroleum gas, with an efficiency of 10%, background count rate of 50-100/second (depending on the gas flow rate), and detection limit of approximately 0.5 KBq. Count rates of 346 and 424 KBq were measured for two of the hot chips, and count rates of 2-10 times the background were measured in 41 of a set of 66 randomly selected other chips. Spectra resembled the known tritium spectrum, but those of high activity chips were compressed toward the low energy end, implying the tritium in these chips is located at greater depths than in the low-activity chips [which may have picked up tritium on their surfaces from the hot chips]. Since the range of the maximum energy (18 KeV) tritium betas is only about 1.5 mg/cm^2, only those betas emitted from a depth of 3.4 microns or less (i.e. very near the surface) can escape from the chips and be measured by beta counting.

Tritium measurements were also confirmed by detection of 4.6 KeV Ti K X-rays using a NaI(Tl) detector and an intrinsic Ge detector. The Ge detector had an estimated detection threshold of 2 KBq for 15-minute counting times and an efficiency of 0.7 counts/second per MBq of tritium. For the NaI detector, the sensitivity was 20 KBq for 5-minute counting times and a detection efficiency of 6 counts/second per MBq of tritium (calibrated using a tritiated Ti standard). Maximum count rates of the hot

chips corresponded to 1.7 to 24 MBq of tritium. The count rates of the hot chips measured with the NaI detector differed by factors of 3-5 with different chip orientations, and strongly localized activity in these chips was confirmed by autoradiography using standard medical X-ray film of medium grain size placed in contact with the chips. This method can detect tritium at greater depths than direct beta counting; the Ti K X-rays have are attenuated by a factor of (1/e) in a thickness of about 9 mg/cm^2 or about 20 microns. However, tritium content in the interior of the chip will still be underestimated.

Tritium levels in the hot chips estimated from the NaI counter were about 1-1/2 orders of magnitude higher than those estimated from the beta counter; this was believed due to uncertainties in the distribution of tritium with depth in the calibration sources used as well as in the chips. The difference was less in the lower-activity chips, again implying tritium to be located deeper in the hot chips. Work is under way to measure the tritium content of the chips by dissolving them in acid and counting the solution by liquid scintillation. However, even using the most conservative values, far more tritium was found in the hot chips than was present in the original D_2 gas (12 Bq). Even if the hot chips are assumed to have absorbed enough deuterium to give a D/Ti ratio of 1, the t/d ratio of these chips after the experiment would have been about 10^{-4}, 9 orders of magnitude higher than that of the gas.

In follow up experiments with a few hundred chips from the same lot, no tritium above the detection limit of 0.5 KBq was found afterwards on any chips, but KBq levels were found after cycling of some of these chips together with one of the hot chips, consistent with the hypothesis that the only tritium production which occurred was in the 4 hot chips. It was noted that no tritium contamination has been found in 12 grams of Ti turnings which have since been prepared for a subsequent experiment, that tritium spot contamination has not previously been reported in Ti, and that if any such tritium had originally been present in the chips, it should have been lost during the outgassing.

JAPAN - EXCESS HEAT
(Courtesy of Dr. Oyama)

Noboru Oyama[1], Takeo Ohsaka[2], Osamu Hatozaki, Yuko Kurasawa, Nobushige Yamamoto, Seiji Kasahara, Naoki Ohta, Yuko Imai[1], Yukio Oyama, Tomoo Nakamura[3], Tokushi Shibata, Mineo Imamura, Yoshitomo Uwamino and Seiichi Shibata[4] ([1]Tokyo U of Agriculture and Technology, [2]Tokyo Institute of Technology, [3]Japan Atomic Energy Research Institute, [4]U of Tokyo, Japan), "Electrochemical Calorimetry of D_2O Electrolysis Using a Palladium Cathode -- An Undivided, Open Cell System," *Bull. Chem. Soc. Jpn.* 63, 1990, pp 2659-2664.

ABSTRACT

The electrochemical calorimetry of the electrolysis of D_2O has been carried out using a Pd cathode in an undivided, open cell fashion, together with measuring the total volume of the evolved gases. The excess heat production, observed using a Pd cathode pretreated by a special procedure, can not be explained as a result of D_2-O_2 recombination alone. However, the present data certainly do not confirm "cold fusion," because no evidence has yet been obtained for neutron, gamma-ray, tritium or helium production during our electrolysis of D_2O with Pd cathodes.

EDITOR'S COMMENTS

Two sizes of Pd cathodes (99.9% purity, from Tanaka Kikinzoku Co.) were used, 6 mm diam. x 5 mm and 2 mm diam. x 20-30 mm. Two annealing procedures were used: heating in air at 1540 C followed by quenching in D_2O, and heating in [low] vacuum at 600 C followed by cooling in D_2 gas. Anodes were Pt, the current density was 60 to 300 mA/cm^2, and the electrolyte contained 0.1 M LiOD. The lengths of the experiments were typically 1-7 days, although data for much longer runs was also presented. The constant-temperature calorimetry system was calibrated using a resistance heater, and H_2O control experiments were also conducted.

After half a week of electrolysis, it was calculated that the heat production in excess of the anticipated Joule (resistance) heating was up to 10 times greater than could be accounted for by the heat of recombination, either based on measurement of the volume of gas evolved during the electrolysis or on the volume which could have been produced at the current density used. (Sample data presented indicated excess heat output of 1.2-1.8 W above expected Joule heating of 4.3 W.) The measured magnitude of the excess was found to depend to some extent on the location of the temperature measurements. Best results were obtained using the higher-temperature annealing treatment.

Further studies using a closed system with complete D_2/O_2 recombination which allows a much simpler energy balance are in progress.

JAPAN - GAS LOADING & ELECTROLYSIS
(Courtesy of Dr. Samuel Faile)

Noboru Taniguchi, Sueki Baba, Kenji Kawamura and Takaharu Gamo (Matsushita Electric, Japan), "Conditions for Cold Nuclear Fusion," *Nippon Kagaku Kaisha*, 1990, pp 992-8 (Japanese).

ABSTRACT

The conditions for cold nuclear fusion were researched using Pd and Ti rods. In researching the conditions of fusion, it is important to examine fusion rates absolutely. In order to detect a very small number of neutrons quantitatively from the other radiation (gamma-rays), the well-type neutron detector composed of an NE-213 liquid scintillator and a pulse shape discriminator was made. This detector detects fusion rate of > 1 x 10^{-22} d-d/s. The phenomena of fusion were investigated for the electrolysis method and the gas absorption-desorption method by this detector. In this electrolysis method, D_2O containing 0.1 mole-dm^{-3} LiOD was electrolyzed under several conditions by using the electrochemical cells consisting of a Pd cathode and Pt anode. There was no difference between the energy spectra during electrolysis and the background energy spectra. On the other side, in a gas absorption-desorption cycle method, generation of neutrons was tested for cast Ti rods. In this case, the 2.452-MeV neutron signal was not detected, but a radiation signal approximately 30-600 times larger than the background was detected during the desorption process of D_2 from Ti. It was assumed from the results of the detector with the NE-213 scintillator that the radiation was gamma rays and that gamma-ray emission came from a p-d reaction in Ti.

EDITOR'S COMMENTS

An article describing earlier electrolysis experiments is Ryoichi Taniguchi et al., *Japan J. Applied Physics* 28(11), 1989, pp L2021-3, reviewed in the January 1990 issue of *Fusion Facts*.

G. WORLD HYDROGEN ENERGY CONFERENCE

In the recently released Proceedings of the World Hydrogen Energy Conference #8, Special Symposium on Cold Fusion (July 23-24, 1990, Honolulu, Hawaii), a substantial fraction of the presentations are represented only by very brief abstracts, and some (such as those of Drs. Gur and Screiber) are the same as in other sources such as the First Annual Conference on Cold Fusion in Salt Lake City. Printing problems also resulted in pages in several articles being out of order. Nevertheless, it is still our opinion that the paper by Dr. Liebert [reprinted in its entirety in the October 1990 issue of *Fusion Facts*] and the paper by Dr. Huggins each are sufficient reason for obtaining a copy of these proceedings [which can be obtained by sending a check for $15, payable to the Research Corp. of the University of Hawaii, to the Hawaii Natural Energy Institute, University of Hawaii, 2540 Dole Street, Holmes Hall 246, Honolulu, HI 96822, USA]. A previous review of the conference was given in the August 1990 issue of *Fusion Facts*. Dr. Huggins' presentation is discussed in section C of this issue.

OTHER PRESENTATIONS

In the review by Dr. Bockris (Texas A&M), in discussing the severe problems which result from irreproducible and sporadic cold fusion effects, it is noted that there are a number of bona-fide classical phenomena which are in certain ways irreproducible because of their natures, such as the time it takes for a fatigue crack to develop in a particular metal under particular conditions, and that since a cracking mechanism has been suggested by some theorists to play a role in cold fusion, such irreproducibility in cold fusion could also well have a theoretical reason. (As noted, Dr. Huggins made a similar analogy.)

In the discussion by Dr. Huang (U. of Hawaii) of his group's 11 month flow calorimetry experiment, using a 0.25 cm^3 Pd pellet, it was noted that although addition of small amounts of H_2O to the electrolyte gradually quenched the excess heat, the effect was only temporary: the excess heat eventually reappeared. It was also noted that SEM (scanning electron microscope) examination of the Pd showed that even after lengthy deuteriding the interior had increased in porosity much less than the surface, which could be seen to be quite porous as a result of the loading.

An additional reference noted in the abstract by Dr. Jones (Brigham Young U) was S.E. Jones, "A Conjecture: Fusion in Metallic Deuterium," in Proceedings of the Workshop on Muon-Catalyzed Fusion, Oxford, U.K., September 1989, in which the possibility of fusion during the formation of metallic deuterium [under extreme pressures] was raised.

The paper by Dr. Kreysa (DECHEMA, Germany) also mentioned an inconclusive attempt to measure correlated neutron and acoustic emissions in Ti and Pd electrodes associated with a possible fractofusion mechanism.

The paper by Dr. Yang (Tsing Hua U, Taiwan, R.O.C.) on electrolytic tritium and heat production reported that 2.2 and 3.5 mm diameter electropolished Pd cathodes, annealed in Ar at 600 C, and Pt cathodes were used. Current density was increased from an initial value of 200 mA/cm^2, but the cells were operated at constant voltage rather than constant current as in many previously reported experiments. The lengths of the experiments were 40-70 days. Final tritium levels in the electrolyte (determined by liquid scintillation and confirmed by an outside laboratory) were on the order of 10^{2-3} cpm, versus approximately 20 cpm initially. An unsuccessful attempt was also made to measure the tritium content of the deuterium outgassed from the electrodes after the experiments. Excess heat onset was noted to have

occurred in one cell within two days but in another only after three weeks; calibration used stainless steel and cold-worked Pd rods, and the maximum heat accountable by Joule heating was also determined using a resistor heater.

The paper by Dr. Bush (Cal Poly) reflected the incorporation of electrochemical factors into the TRM model previously presented at the First Annual Conference on Cold Fusion. (In summary, the excess heat is proposed to depend on the temperature, current density, and hydrogen overvoltage. It is suggested that in experiments in which other factors are held constant, dips in output will occur at particular values of the remaining parameter, and aside from these dips, output will generally rise with increasing temperature or current up to a certain point, but then drop more and more rapidly to zero ("rollover"). Further work on the model has since been presented at the Anomalous Nuclear Effects conference at BYU [*Fusion Facts*, November 1990]. However, these Proceedings do provide copies of experimental data by Dr. Eagleton of Cal Poly presented at both conferences, showing a sawtooth-shaped dip (with dimensions consistent with the TRM model) in the power-versus-current plot for one experiment, and a termination of the excess heat at high temperature is seen in another. A suggestion that the quantum mechanical behavior of the system in the model may also minimize emission of secondary X-rays and gamma rays was also briefly discussed.

The presentation by Dr. Dini (U. of Pisa, Italy), which suggested that cold fusion would remain in its infancy for many years due to present reproducibility problems and the need for new theories, also discussed the large amounts of money currently spent trying to overcome major problems with hot fusion and suggested that this technology is also several decades from commercial application. (Since the conference, U.S. government projections have in fact shifted the anticipated date to the mid-21st century.)

The presentation by Dr. Hora (U. of New South Wales, Australia) discussing enhanced screening at metal surfaces suggested the use of electrodes composed of many alternating layers of Ti and Pd or Fe (such as steel). In addition, a figure [from F.A. Lewis, The Palladium-Hydrogen System, Academic Press, New York, 1967] is reprinted comparing Pd and Ti with Th, Ce, Zr, Ta and V, metals which can take up equally large or even larger amounts of hydrogen (up to twice as much as Ti and five times as much as Pd, if surface oxides were not a problem). It is also interesting to note that, of these metals, Pd shows by far the greatest drop in solubility at temperatures of a few hundred degrees C. This could be a strong argument for trying not only Pd but also other metals and alloys with high hydrogen solubility in the molten-salt cells described by Drs. Liebert and Liaw.

For those interested in economic factors, the presentation by Dr. Hurtak (Technology Marketing Analysis Corp.) notes a current price for D_2O of reasonably high purity (99.75%) of $273 per kilogram [approximately $120/lb], and a price of approximately $2000/lb for Pd; costs for other electrode materials such as Ti are much lower. If cells were optimized to maximize rather than minimize tritium generated as a byproduct, its current selling price is $10,000 per gram.

The presentation by Dr. Kim (Purdue) discussed the metal/insulator/gas cells of the type developed by Dr. Claytor in greater detail than was possible at the Anomalous Nuclear Events conference at BYU in October [*Fusion Facts*, November 1990]. A mechanism involving acceleration of deuterons in gas pockets formed in such porous materials was proposed, and it was suggested that a pulsed magnetic field synchronized with the pulsed high voltage could increase fusion rates.

H. SHORT ARTICLES

COLD FUSION WITNESSING AGENT

By Dr. Dennis Cravens

[About the Author: Dr. Cravens is a Professor at Vernon Community College, Vernon, TX and a consultant for various government agencies.]

Currently there are many theoretical views of the exact nuclear reactions involved in the cold fusion process. The ratio of the tritium to neutron emission is quite high and is most likely of the order of 10^8 or 10^9. It is difficult to detect charged particles formed within the metal lattice. Charged particles are rapidly stopped due to interaction with the valence electrons of the metal. Prof. Ed Cecil [1] has used very thin titanium foils which allowed some charged particles to escape the lattice. His work indicates there is a release of high energy charged particles with energy about 4 to 5 MeV. The high levels of energy release in the molten salts cells at the University of Hawaii [2] produced helium within the palladium metal lattice.

If the release of charged particles is the primary route to the formation of thermal energy from cold fusion, then a high flux of alpha particles or tritium particles is generated within the metal host lattice during the nuclear fusion events. Such particles cannot escape in large numbers from an operating cell. Instead they are stopped and captured by electrons in the conduction bands of the host lattice. These particle are held interstitially as $_4$He and $_3$H (tritium). There is a way, however, to detect the particles and their energies within the metal host lattice. **The metal lattice can be doped with a small amount of a witnessing agent.** For example, the addition of a small

amount of Beryllium should produce neutrons from the alpha + Be --> C + n nuclear reaction.

Drs. Storm and Talcott (Los Alamos) [3] did try a mixture of Pd and Be, but only looked for tritium production. (They found none in this experiment.) Storms has stated that the alloys of Be of more than 10% were extremely hard and very difficult to work. The suggestion here is to use levels of the order of 0.1% of the witnessing agent to be involved with any alpha or tritium production within the lattice. A wide range of witnessing agents are possible, for example, B or U could be used. It is likely that the B or U would be less likely to interfere with the deuterium uptake by the lattice. A wide range of agents are known which produce gamma rays or neutrons reacting with energetic charged particles.

This suggestion for the use of a witnessing agent could be tried by someone properly equipped both with working cold fusion cells; with the skills to make the electrodes; and the equipment to measure the nuclear by-products. Witnessing agents are one of the few way we have to be able to determine, more precisely, which particles and what energy levels are being produced within the metal lattice during the operation of a cold fusion cell.

Cold fusion nuclear reactions are definitely not easy to achieve. Unfortunately, there are no pat answers for success and educated speculation may be useful. The following information comes from combing the theoretical insights of R. Bush [4], and Chubb & Chubb [5], the experimental views of Storms and Talcott-Storms [6], and some of my own understanding.

Coherent states seem to play a role in both the interaction of deuterium and the energy release. In Bush's model, it is the deuterium moving within a regular lattice array which allows constructive reinforcement of the quantum mechanical waves. In Chubb's theory this concept is extended to also require coherence in the energy absorption due to the inverse Mossbauer effect.

From the experimental considerations, Storms has pointed out the difficulties in retaining a uniform Pd lattice during loading and deloading of D. The real root of the problem is there is an alpha to beta phase transition for Pd. This transition causes the metal to alter its dimensions and therefore induces stress. The result is that many experimenters have chosen to use a slow initial loading of the Pd at low current densities which lowers the amount of internal stress.

The suggestion made here is to make the initial loading at elevated temperature under magnetic field. Temperatures above 300 C avoid the alpha to beta phase transitions with the Pd during the deuterium loading. The result is that the Pd lattice can be loaded with deuterium without adjacent crystal grains being in a different phase. This process should decrease the internal stress of the metal lattice during loading.

It is suggested that this approach (loading at high temperatures) may be a major reason for the recent success of Liaw et al. [2] at the University of Hawaii (although the role of the hydride to prevent oxidation is also important). Also, there are reasons to believe that higher temperature and higher current densities should be generally beneficial.

The use of magnetic effects is more difficult to explain. The deuterium wave functions are generally separated into space and time components (energy and spin). For true coherence, both the energy and spin alignments of the deuterons must be the same. A magnetic field can effect the nuclear alignments of the deuterons within a highly paramagnetic material. It would seem that coherence can best be achieved when both bound and mobile deuterium (deuterons) within the lattice are spin aligned. Such alignment can drastically and unexpectedly affect the cross section for nuclear events [7].

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[2] Bor Yann Liaw, Peng-long Tao, Patrick Turner, Bruce E. Liebert (U. of Hawaii), "Elevated Temperature Excess Heat Production Using Molten Salt Electrochemical Techniques", *Special Symposium Proceedings - Cold Fusion*, World Hydrogen Energy Conference #8, p 49-60, July 23-24, 1990, Honolulu, Hawaii. [See also *Fusion Facts*, Vol 2 No 4, Oct 1990, pages 1-14 for a reprint and an extensive review of all references.]

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[6] Edmund Storms & Carol Talcott-Storms, (Los Alamos National Laboratory), "The Effect of Hydriding on the Physical Structure of Palladium and on the Release of Contained Tritium", *Proceedings of Anomalous Nuclear Effects in Deuterium/Solid Systems,* Brigham Young University, October 22-24, 1990 (in press). [See also review in *Fusion Facts,* Vol 2, No 5, pp 25-27, Nov 1990.]

[7] D. Cravens (Vernon College, TX), "Nuclear Spin Curtails Neutron Production", *Fusion Facts*, Vol 1, No 4, pp 11-12, October, 1989. Note: This article was based on the work by C.K. Chol, "Nuclear Spin Polarization of Advanced Fusion Fuels", *U.S. Air Force Report F04611-88-c-0014.* See also *Science News*, Vol 138, Nov 3, 1990, that reports the work of Alan Krisch showing large and unexpected spin effects in proton-proton interactions.

EDITOR'S COMMENTS

The addition of small amounts of Be appears to have the potential for allowing the measurement of much lower cold fusion rates than are ordinarily achievable in electrolysis experiments and others not well suited for direct charged particle measurements. In addition, doping only the interior of a sample of sufficient size could help establish whether the reaction is occurring only at the surface or in the entire sample, since the range of a 20-25 MeV alpha particle in Pd is on the order of only 0.1 mm.

However, it should be stressed that witnessing agents, such as beryllium or boron should be used only with caution. Heat and tritium levels reported in previous experiments indicate that this method could generate lethal levels of neutrons if overly successful. (Moreover, burst patterns of neutron emission in past experiments suggest that fusion rates may vary by at least several orders of magnitude with time, in a possibly irregular fashion; thus continual monitoring would be necessary even if no neutrons are seen initially in an experiment with a doped sample.) In addition, the chemical toxicity of beryllium in certain forms is especially high. As noted, an experiment using Be-doped Pd was performed by Drs. Storms and Talcott-Storms, however, the cell with Be was reported to be inactive.

Bombardment of Be with alpha particles is particularly effective in releasing neutrons: For example, the yield of the ^{9}Be(alpha,-n)^{12}C reaction is approximately 1 neutron (up to 13 MeV) per 2200 alpha particles from Ra (primarily 23.67 MeV), and approximately 1 neutron (up to 11 MeV, average 4 MeV) per 12,500 alpha particles from Po (primarily about 17 MeV). However, as noted by Dr. Cravens, a few other possible doping agents also exist. In particular, doping with boron could be almost as successful; the ^{11}B(alpha,n)^{14}N reaction using alpha particles produced by Ra decay yields approximately one neutron (up to 6 MeV) per 5500 alpha particles [Nuclear and Radiochemistry, 3rd edition, Gerhart Friedlander et al., 1981].

As noted by Dr. Cravens, the method is not selective for alpha particles; even if the product of the cold fusion reaction is tritium or another energetic nucleus, collisions of these particles with Be could also cause secondary reactions which emit neutrons.

If, on the other hand, it is found that addition of Be (or B) does not tremendously increase neutron production in active cells, this would support those theories which predict the products of the cold fusion reaction have unusually low kinetic energies. (This would also be consistent with the evidence provided by the scarcity of secondary 14-MeV neutrons in electrolysis experiments relative to the amounts of tritium measured.)

NEUTRON MEASUREMENTS AND COUNTING STATISTICS

by Michael Dehn

[Michael Dehn is Associate Editor of *Fusion Facts.*]

This article is intended to provide an overview of neutron detection for those whose expertise is in other areas, and also to outline for the layperson the statistical considerations in measurements. Primers in future issues will summarize the basics of other types of measurements (tritium, charged particle, helium, gamma ray, X-ray, and heat measurements), relevant aspects of electrochemistry, metallurgy, and nuclear physics, and types of cold fusion experiments.

The neutron detectors used by a number of current cold fusion groups, as described at the October 1990 conference at Brigham Young U, were also described in the neutron section of the November issue of *Fusion Facts*. (For example, particularly sophisticated systems are described in the presentations by Drs. Menlove and Czirr.)

Purpose

Any neutron emission measurements can be important in establishing the occurrence of a nuclear reaction. However, given the very low neutron/tritium branching ratio of 10^{-7-9} reported in various cold fusion experiments and the difficulty in measuring low levels of neutrons, the question first arises, why is so much effort still given to neutron measurements? (Detection efficiency is not the

answer; the efficiency of tritium scintillation counting is typically higher than that of neutron counters.) In fact, there are various potential answers to this question, other than simply ready availability of a good neutron detector and/or disbelief in the abovementioned branching ratio reports.

One answer lies in the 12.3 year tritium half-life. If we must measure the tritium decay rather than the triton (charged particle) production, our sensitivity is greatly lowered (by a factor of 1.77×10^{-9}). Thus, at a neutron/tritium branching ratio of 10^{-9}, tritium decays and neutron emission will be approximately equally common even though vastly more tritium is produced.

A second answer lies in the fact that neutrons provide an instantaneous measure of the reaction rate, whereas tritium assays measure cumulative production, which may improve detection limits. In practice, both a detailed time-course and a time average or total production may be of interest.

A third answer is that the neutron energy and the branching ratio may provide useful information in the development of theories of cold fusion. Anomalous branching ratios place significant constraints on cold fusion theories. Also, in conventional fusion, the kinetic energies of each of the products is characteristic of the particular nuclear reaction which is occurring. For instance, conventional d + d --> n + ^{3}He fusion reactions generate neutrons with energies of 2.45 MeV (plus a presumably negligible contribution from the kinetic energies of the original deuterons); h + d or the d + t reactions would produce neutrons with different characteristic energies.

Another possible answer is that the branching ratio may vary depending on the experimental conditions, especially if the neutrons are due mainly to secondary reactions. For example, it is conceivable that neutrons in new types of experiments (such as those of Yamaguchi and Nishioka [1] or plasma focus experiments) are not accompanied by comparatively larger amounts of tritium.

(Additional minor points are that tritium levels in an open system will increase during electrolysis, that tritium assays may require disturbing the system to replenish the solution volume, and that any production is significant because conventional neutron production rates at room temperature would not be measurable even with the best detector in the world unless a special mechanism is available to accelerate deuterons to high velocities.)

In neutron measurements, the extent to which neutrons occur in bursts and the abilities of the detector may determine whether the goal of an experiment is to measure the average production rate or the production during neutron bursts. In addition, the type of detector available and the design of the experiment may determine whether the kinetic energies of the neutrons are also measured.

It is also worth noting that, given an extremely low ratio of neutrons to tritium or heat, the neutrons which are being measured need not be due to the primary fusion reaction; energetic nuclei produced can also go on to cause secondary reactions which can generate neutrons and other species, as can sufficiently energetic gamma rays, electrons, etc. Indeed, if the tritium measured had been produced with the 1-MeV kinetic energy expected for conventional d-d fusion, 14-MeV secondary neutrons alone, produced when the tritons colliding with deuterium atoms cause the reaction d+t-->n+^{4}He, would ordinarily be expected to give an apparent n/t branching ratio significantly greater than $10^{-7\text{-}9}$.

Finally, it should be cautioned that reliance on neutrons alone (or on other nuclear products) to assess reaction rates or optimize experimental conditions could be misleading if the branching ratio is not fixed or if most neutrons are secondary. In an extreme example, if achievement of a cold fusion reaction producing only helium without any accompanying side-reactions creating neutrons or tritium is possible, only heat measurements would be guaranteed to accurately establish whether the experiment had achieved negative or positive results.

Fast and slow neutrons

In attempting to measure neutrons, it should be noted that specialized neutron detectors are generally required: ordinary radiation detectors such as geiger counters are insensitive to neutrons because neutrons, not being electrically charged, cause negligible ionization. In addition, however, it is vital to note that neutron detectors are often sensitive primarily to either energetic (fast) or thermal (slow) neutrons, and that energetic neutrons passing through matter will gradually lose their kinetic energy through collisions ("moderation"), eventually becoming thermalized.

Thus, only a detector sensitive to fast neutrons would be appropriate in an experiment in which very little matter is present between the sample and detector, while only a detector sensitive to slow neutrons would be appropriate where large amounts of moderator separate the source and detector. (This is why, for instance, slow neutron detectors are used more often in electrolysis experiments than in gas-loading experiments.) Finally, if a high-quality neutron energy spectrum is desired, the experiment must be designed in such a way as to minimize thermalization as much as possible; for instance, this is why foil samples and gas loading are often used in such cases. (The same applies in charged particle experiments.)

Thermalization is most rapid in moderators containing large numbers of light atoms (i.e. hydrogen and deuterium would be especially effective). For this reason, a few tens of centimeters of water, paraffin, polyethylene, or similar substances are frequently used to surround detectors sensitive to thermal neutrons, in order to ensure that all neutrons from an experiment are slowed sufficiently. (Once thermalized, neutrons will eventually be captured by atoms (or decay), but this process takes much longer than thermalization unless elements with unusually high neutron capture cross-sections, such as Li, B or Cd, are present.)

Statistical considerations

The signal-to-noise (S/N) ratio in an experiment will be affected by several factors: the sample's neutron emission rate, the detector efficiency, the background count rate, the counting time, and the variability of the background. In cases in which the S/N ratio is not high, results are best expressed in terms of how many standard deviations (sigma) they are above the average background counting rate. For example, it may be noted in a report that a particular measured sample counting rate of 1.5 ± 0.2 per minute is 5 sigma above, or three times, the background counting rate of 0.5 ± 0.1 per minute. The standard deviation is typically inversely proportional to the square root of the number of counts. Thus, if the counting rate in the above example had been measured over a day, the result would have been only a statistically insignificant 1 sigma above background if a counting time of only 1 hour had been used instead. The significance of this result could have been increased greatly by decreasing the background counting rate through shielding, and could have been increased somewhat by increasing the detector efficiency.

Counting statistics will ordinarily follow a roughly Gaussian or normal distribution, such that about 32% of measurements will fall more than 1 sigma from the mean, 4.5% will fall more than 2 sigma away, and 0.27% will fall more than 3 sigma away simply due to random chance. It is for this reason that only results more than 3-5 standard deviations above the background or controls are considered potentially significant. It should be noted, however, that systematic errors can cause gross deviations from this behavior; for example, in surface sites large variations in the background neutron count rate can occur over periods of hours or days due to barometric pressure variations and changes in cosmic ray activity.

The numbers of counts in individual counting intervals can typically best be approximated by a Poisson distribution. (Specifically, the equation defining the Poisson distribution is $P(i) = mu^i \times (e^{-mu})/i!$, where P(i) is the probability of i counts being measured during the time interval and mu is the mean.) Thus, as an additional statistical test, it is common for experimenters to compare the numbers of counting intervals with particular number of counts against that expected from the Poisson distribution; ideally the background will fit the Poisson distribution well, indicating that the equipment is functioning properly, while neutron spikes could cause the number of intervals in the sample spectrum with the highest counts to exceed that predicted. It is worth noting that similar deviations from the Poisson distribution in the background spectrum need not suggest experimental errors, but could arise from a significant contribution from cosmic rays, which likewise may show a burstlike behavior.

Optimization

The efficiency of a neutron counter is the fraction or percentage of neutrons of a given energy which are detected by the counter. Efficiencies can vary considerably, from fractions of a percent (especially for counters using coincidence methods described below) up to a few tens of percent. For fast neutron detectors, the efficiency typically varies significantly with the neutron's energy. Given the approximate efficiency, the number of source neutrons which would have been responsible for the number of neutrons detected can be estimated; for example, at an efficiency of 1% a measured rate of 10 neutrons/sec would correspond to an emission of 1000 n/s. Unfortunately, some references which do not cite both the numbers of measured and source neutrons do not quote the efficiency, preventing such a calculation. (In rare cases, a reference may also not indicate whether the rate quoted is of source or measured neutrons. This distinction can be very important if the detector efficiency is low.)

Background counting rates in different experiments may vary even more dramatically than detector efficiencies, from multiple counts per second at surface sites with minimal shielding to fractions of a count per week in the best-shielded sites with the best detectors [ex. 2]. In some cases, signal-to-noise ratios can be greatly improved (even though the detector efficiency, and thus the count rate, are decreased) by the use of a coincidence method, in which only "correlated" counts -- two or more counts occurring within a certain time interval (typically 50-150 microseconds) -- are measured. This method is ideal if background counts are primarily uncorrelated (sufficiently low contribution from cosmic rays, etc.) but sample counts occur primarily in bursts. (If even the correlated count rate is still large because of a high-background environment, it would also be possible to look only at events with a high multiplicity -- i.e. limit the events counted to those in which the burst contains at least a given number of neutrons, say 10.)

Low-level neutron measurements are typically performed at underground sites in order to sharply reduce the cosmic ray background. In addition, cadmium or boron-

containing (ex. borax) shielding may be used to absorb thermal neutrons; since such shielding is relatively ineffective against fast neutrons, this may also be surrounded by a moderator such as paraffin which first thermalizes any fast background neutrons. In addition, lead may be useful as gamma shielding, since the gamma ray background is typically much greater than the neutron background and many fast neutron counters can only imperfectly discriminate the two. Two potential pitfalls in the use of shielding are also worth noting. First, lead should be of the "low-activity" type (i.e. as old as possible), since lead only a few years or decades old will contain small amounts of naturally occurring radioactive species such as ^{210}Pb (half-life 22.3 years, produced by the decay of radon). Second, since neutrons may follow zig-zag courses due to scattering off walls, ceilings, etc. ("sky-shine"), shielding must completely surround the detector and cell in order to intercept all background neutrons.

Ideally, in order to maximize efficiency, the neutron detector would completely surround the sample (referred to as a "4-pi geometry"). This geometry can in fact be approximated by "well counters", in which the sample is placed in a well running through the center of the counter(s). In addition, it would be desirable to have a background counter, located nearby but similarly shielded, in operation at the same time as the sample counter. (In fact, in the ideal case background counter(s) would completely surround the sample counter. This geometry is sometimes approached in designs using two concentric rings of ^{3}He counters.) It would also be desirable if more than one independent counter could be used to measure the neutron output from the sample at the same time. If this is not possible, then a demonstration that neutron count rates on the background counter increase and count rates on the sample counter decrease as an active sample is moved from the sample counter to the background counter would be valuable. If only one counter is available, a demonstration that the count rate decreased as the sample was moved away from the detector could provide confirming evidence; the count rate above background should be proportional to $1/r^2$, where r is the distance between the source and detector.

The lower the neutron emission rate being measured, the more critical the optimization of the signal-to-noise ratio becomes, and the greater the need for long-term background measurements, statistical analyses, systematic tests of the detector sensitivity to all factors which can introduce noise, and appropriate expertise on the part of the experimenter, in order to indicate that the data is not due to spurious counts. In some cases, a great advantage may be gained by collaborative efforts which allow the most sophisticated neutron detection equipment at other facilities to be used; for instance, in 1991 some data may be obtained at possibly the best neutron detector in the world, in the Kamioka mine facility in Japan [3].

Types of detectors

1) Fast neutron detectors are often based on a proton-recoil scintillation technique: during scattering of a fast neutron by a hydrogen atom in the detector body, the hydrogen (proton) picks up sufficient kinetic energy (recoil) for it to excite a molecule of the scintillator compound, and the resulting light can be detected with a photomultiplier. For instance, the very commonly used NE213 detector is of this type. Either liquid or solid (plastic, etc.) scintillators can be used; these frequently are composed of organic scintillators. This technique can also be used to determine a rough neutron energy spectrum. Note that if neutrons emitted by the sample are predominantly of a particular energy (such as 2.4-2.5 MeV), the isolation of neutrons of this energy could increase the signal-to-noise ratio in the experiment. (Note that some references which report detection of such neutrons may cite more significant figures than are actually measured, such as 2.45 MeV when neutrons were actually measured to the nearest 0.40 MeV.) The efficiency of fast neutron detectors can be reasonably high, but this may be offset by a sensitivity to gamma rays as well as neutrons (leading to higher backgrounds). Sensitivity to thermal neutrons (due to neutron capture reactions in the scintillator) is typically low.

Various refinements are possible to improve gamma rejection (neutron/gamma discrimination): First, pulse shape discrimination can be used to reject counts whose shapes (especially widths) are more characteristic of gamma rays. Second, if the background is still dominated by gamma radiation, neutron/gamma discrimination could be greatly improved (at the expense of efficiency) by using coincidence techniques -- i.e. requiring that two or more scattering events, separated by an appropriate short time interval, must occur while the neutron is passing through the scintillator. Third, a material such as ^{6}Li could be added which gives a signal when it absorbs a thermal neutron; the background is again lowered at the expense of efficiency by requiring the initial signal from the fast neutron to be followed after a reasonable period of time by a signal of the proper energy for the reaction of the same neutron (once thermalized) with the Li [ex. 4].

2) Slow neutron detectors are often based on neutron capture reactions involving isotopes such as ^{3}He, ^{10}B, or more rarely ^{6}Li in the detector which have especially high cross-sections for thermal neutrons. Examples are the commonly used ^{3}He and BF_3 counters, which are simply proportional counters filled with the gases indicated. The nuclear reactions measured are the $n+^{3}He \rightarrow p+t$ and $n+^{10}B \rightarrow ^{4}He+^{7}Li$, respectively. As noted previously, such a detector will be sensitive to fast as well as slow neutrons only if the detector is surrounded by a sufficient thickness of a moderator.

Note that the high voltage in such counters is typically sensitive to high humidity and possibly also to electromagnetic interference; thus moisture control and RF shielding are desirable. In addition, ^{3}He tubes with stainless steel rather than aluminum walls are desirable for low-level measurements, due to their lower intrinsic radioactivity. Detectors containing up to several dozen ^{3}He tubes may be used in order to attain optimum efficiencies.

Various refinements are possible: First, tubes may be grouped into several sets, each with its own electronics (possibly including its own high voltage line) and readout; similar counting rates in each set can thus help establish that high count rates are not due to instrumental problems. Second, "veto" counters on the same high voltage line can help to reject spurious counts; signals recorded simultaneously by the sample counters and by such a nearby ^{3}He counter would be rejected by the electronics. (In some cases such veto counters may be rendered insensitive to actual neutrons -- for example, by surrounding it with sufficient Cd to stop most thermal neutrons in the lab.) Third, an outer ring of tubes with a separate readout could be added to demonstrate that high counting rates are due to a source inside rather than outside the inner ring.

3) Neutron spectrometers with considerably better energy resolution than normal scintillation counters also exist. For instance, the time-of-flight instrument described by Dr. Iazzi at the BYU conference [5] is of this type, as is the spectrometer used in tests of Dr. Jones' cells by Dr. Moshe Gai of Yale in 1989. (Such detectors are also able to reject gamma rays and relativistic particles.) Again, such experiments would involve optimization of the geometry so as to prevent collisions of the emitted neutrons before they reach the detector.

4) Finally, a variety of dosimetry methods (which give only the cumulative neutron emission over the course of an experiment) can also be used, such as thermoluminescence or appropriate types of track detectors. In addition, if the thermal neutron flux is sufficiently high, the gamma radiation produced by neutron activation (neutron capture reactions which give rise to isotopes which decay by gamma emission) can be used [ex. 6,7].

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DO KNOWN EVENTS CONSPIRE TO PRODUCE COLD FUSION OR IS A NEW PHENOMENON INVOLVED?

By Dr. Samuel Faile

[About the Author: Dr. Faile is a consultant and a correspondent to *Fusion Facts*. He lives in Cincinnati.]

A combination of various known factors such as experimental parameters (current density, temperatures, charging time, voltage), de Broglie waves, Bragg reflections, resonating effects, excited states, inverted populations, superradiance, laser activity, soft X-rays, f and d electrons, Jahn-Teller interactions, coherent effects, collective phenomena, special deuterium plasmas, plasma/solid interactions, tunneling mechanisms involving effectively reduced deuterium masses, diffusion rates, screening effects, surface polarization, double layers such as swimming electron layers, ultra high dielectric fields, interface and grain effects, special impurities, barrier junction effects, lithium diffusion layers, movement of heavy ions, dislocation loop activity, dendrites in D_2

bubbles at high potential, electrolytic pressure effects in electrodes, chain reactions, electron capture, and neutron exchange could conspire [in some combination] to produce cold fusion.

On the other hand, underlying cold fusion could be a new basic phenomena such as new particles (itons?), fermion interaction with axion cosmic string loops, instanton (wormhole) interactions, transformations to strange matter (quark energy), skymion decay, metallic deuterium, superconducting clusters, QED [Quantum Electro-Dynamics] vacuum phase charges to form special droplets, fermions with increased negative charge, anyon interactions, boson condensations, new chaotic phenomena, special fractal factors, interaction with vacuum fluctuations, new space-time effects, new magnetic or gravitational interactions, and new catalytic particles.

Less surprising would be polarization of deuterons at low energies, quasi-particles, heavy fermions, deuterium acting as a catalyst, delocalized deuterium states, cluster fusion, some skewed energy distribution of particles or alteration of tunneling mechanisms. Of course, in addition to all of these possibilities there could be other factors considered in lesser known theories.

Some people believe that the cause of cold fusion is still completely unknown. In any event the winning explanation of cold fusion should explain a reaction rate that has a range roughly 10^{-23} to 10^{-8} nuclear events per deuterium pair per second rather than the old expected value of $10^{-65.}$

EDITOR'S COMMENTS

Dr. Faile has, with tongue in cheek, reviewed the list of what one or more theorists have called upon to explain the important and challenging reality of cold fusion. His second list contains concepts that have been suggested as required to explain cold fusion. Hopefully, someone will properly apply Occam's Razor and trim the list to a few **real** concepts.

I. CONFERENCES & CALL FOR PAPERS, ETC.

2ND ANNUAL CONFERENCE IN ITALY IN 1991

Dr. Fritz Will, Director of the National Cold Fusion Institute, has announced that the Second Annual Conference on Cold Fusion will be held in Italy in the Spring of 1991. Papers on all aspects of cold fusion will be considered. For information call (801) 581-5571. Further details will be published here as soon as they are available.

NEXT ANOMALOUS NUCLEAR EFFECTS CONFERENCE TO BE HELD IN ITALY IN 1991

Professor Steven Jones, BYU, announced that the next Anomalous Nuclear Effects In Deuterium/Solid Systems Conference will be held in Italy in the fall of 1991.
Fusion Facts will publish further information about time, location, and call for papers as soon as that information is received.

JOURNAL CALLS FOR PAPERS

Courtesy of Subbiah Arunachalam, Editor, IJT

The Indian Journal of Technology (the third journal -- after *J. Electroanal. Chem,* and *Nature* -- to publish an original research paper on cold fusion) invites papers. Both original research papers and critical review articles in all areas of cold fusion are solicited.

Manuscripts may be sent, in duplicate, to Editor, Indian Journal of Technology, PID, Hillside Road, New Delhi 7110012, India.

TECHNICAL NOTES IN *FUSION TECHNOLOGY*

Fusion Technology has initiated and is continuing a very successful section for "Technical Notes" on cold fusion. This section in intended for fast publication of important papers on new directions, innovative ideas, and new results. Over the past year over 48 papers on cold fusion have been published, making *Fusion Technology* one of the premier professional journals covering this area.

Technical Notes do not have a page limit but they typically run 2-4 journal pages (1 journal page approx. = 3 double-spaced typed pages). A brief abstract is required. ASCII format computer media can be accepted.

Technical Notes will be reviewed but the process stresses rapid response. **Reviewers are instructed to consider Technical Notes as speculative, sometimes incomplete work that should be judged on the basis of innovation, originality, and importance to fusion power development. Appropriate citations to prior work are also essential.**

Deadlines for future issues are as follows:
July 1991 issue: January 30, 1991
August 1991 issue: February 20, 1991

Send manuscripts to: George H. Miley, Editor, *Fusion Technology,* Fusion Studies Laboratory, University of Illinois, 103 S. Goodwin Avenue, Urbana, IL 61801. Fax (217) 333-2906. Phone (217) 333-3772.

CONFERENCE PROCEEDINGS AVAILABLE

Copies of the Proceedings of Anomalous Nuclear Effects in Deuterium/Solid Systems Conference, Oct 22-24, 1990 can now be ordered. The estimated publication date for the conference proceedings is currently March 1991. Copies can be ordered by sending a check for $55, payable to S & J Scientific Co., to:
Prof. S.E. Jones, Physics Department
Brigham Young University
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The First Annual Conference on Cold Fusion Conference Proceedings, is now available. The proceedings include the papers presented March 28-31, 1990 at the conference.
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COLD FUSION INFORMATION

The following publications have been helpful in publishing articles on cold fusion:

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Recently added new section on Cold Fusion
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