FUSION facts

A Monthly Newsletter Providing Factual Reports On Cold Fusion Developments

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CONTENTS FOR MARCH 1991

COMING IN APRIL 1991

Fusion Facts will receive and report on two patent applications that claim to provide **a method by which one can construct a heavy-water cold fusion cell that provides excess heat and is repeatable.** The problem of repeatability has been partially or fully solved by at least four groups of researchers. See page 3.

TOUR RATES FOR FUSION CONFERENCE

Special rates are available with TWA for round trip to Europe for $649. Payments must be made by April 8, 1991. *Fusion Facts* is making arrangements for Conference Rates under $750 round trip. Call Clawson Travel 1-800/825-2976, U/U Office.

A. CONFIRMED ^{4}He WITH HEAT

COLD FUSION CELL PRODUCES ^{4}He IN AMOUNTS TO EXPLAIN MEASURED EXCESS HEAT

Courtesy of Drs Melvin H. Miles and Ben Bush

B.F. Bush & J.J. Lagowski (Chem Dept, U of Texas Austin), M.H. Miles & G.S. Ostrom (Chem Div, Research Dept, Naval Weapons Center, China Lake, CA), "Helium Production During the Electrolysis of D_2O in Cold Fusion Experiments", A Preliminary Note accepted for publication in the J. Electroanal Chem (probably in April 1991), 13 manuscript pages, 11 ref.

AUTHORS' LETTER

"... Recently we completed an exhaustive study designed to determine whether the excess heat observed during electrolysis correlates with the production of helium in the electrolytic cells. ... We wish to bring the results of this study to your [readers] attention. ...

"Essentially, the experimental evidence cited in the manuscript correlates the detection of helium to the observation of excess heat in electrolytic cells (corresponding to the Pons and Fleischmann design); ^{4}He was detectable in the effluent gas from the cell when excess heat was observed. Furthermore, no ^{4}He was detectable when no excess heat was observed. Equally as important as the excess heat to helium correlation was the evidence that contamination of the effluent gas samples was not a factor in the experimental results.

"The conclusions derived from our work should go a long way towards dispelling the controversy surrounding the topic of cold fusion. The production of ^{4}He from a LiOD-D_2O/Pd system can only be explained by a fusion process. We hope you will consider including a synopsis of our manuscript in *Fusion Facts* as a matter of interest to your readership." /s/ Dr. Melvin H. Miles & Dr. Ben Bush.

Fusion Facts is pleased to present this important work as our lead article in this March 1991 issue. See page 2. Ed.

CONFIRMED ^{4}He WITH FUSION HEAT (cont'd)

AUTHORS' INTRODUCTION

Our interest in the cold fusion process was piqued by the apparent lack of systematic investigation into the composition of the gaseous products produced during the electrolysis of D_2O. A critical issue in determining whether or not the cold fusion process exists is the quality of the evidence concerning the composition of the gaseous products. The low intensity of neutrons has prompted proposals of other fusion processes such as

d + d --> ^{4}He + gamma
p + d --> ^{3}He

Accordingly, we report the results of experiments designed to detect helium in effluent gases from electrolysis reactions at palladium cathodes while rigorously excluding possible helium contamination from other sources. The calorimetric electrolysis experiments reported here were performed at China Lake, and the analyses designed to establish the composition of the effluent gases were performed in Austin.

AUTHORS' CONCLUSIONS

Our cold fusion experiments show a correlation between the generation of excess heat and power and the production of ^{4}He, established in the absence of outside contamination. This correlation in the palladium-D_2O system provides strong evidence that nuclear processes are occurring in these electrolytic experiments. The major gaseous fusion product in D_2O-LiOD is ^{4}He rather than ^{3}He. No helium products are found in H_2O-LiOH experiments. These results add to the accumulating evidence for cold fusion that involves 12 countries and more than 70 laboratories. [See also 1,2]

EDITOR'S COMMENTS

A project leader who plans to measure nuclear byproducts from cold fusion must first develop an electrochemical cell that produces excess heat consistently. The design and operation of such a cold fusion cell is a dramatic achievement that has been accomplished by and reported by Miles et al [3,4]. The second task is to collect evolved gases (excluding air) and identify ^{4}He in the presence of possible ^{3}He, HT, HD, and D2. Successful results are reported in this paper.

The nuclear reaction: d + d --> ^{4}He + 23.85 MeV is the most energetic of all fusion reactions. A relatively small amount of ^{4}He accounts for considerable heat. Therefore, great care must be taken to ensure that the experimental design excludes any helium contamination from the atmosphere. The authors have designed and carried out an elegant experiment using using suitable controls to ensure that their experimental data is accurate and all possible atmospheric contamination is avoided.

Basically, a cold fusion electrochemical cell was designed to exclude air while collecting all evolved gases in 500 ml sample flasks. The gathered effluent gases were then treated to remove all moisture, deuterium, oxygen, and all but inert gases such as helium. The inert gases (mainly helium) were then injected into a Bell & Howell 21-491 mass spectrometer. This spectrometer has sufficient resolution to separate the D_2 and ^{4}He mass peaks when viewed on an oscilloscope.

The experimental findings are as follows:

1. ^{4}He was observed well above background. ^{3}He was not observed to be present.

2. Helium was found only when cells were producing excess heat.

3. Helium was not found in sample flasks used for atmospheric contamination tests nor from effluent from control cells (using water and LiOH).

4. The amount of helium measured was calcultated to be roughly the amount that would be expected for the observed excess heat using the d + d --> ^{4}He nuclear reaction.

IMPLICATIONS

Bush, Lagowski, Miles, and Ostrom have dramatically shown that cold fusion electrochemical cells produce a nuclear byproduct that cannot be created by chemical means. In addition they have answered the demanding question, "What is the nuclear byproduct of cold fusion and is it consistent with measured excess heat?"

Fusion Facts urges our DoE National Energy Laboratories to contact Dr. M. H. Miles, Chemistry Division, Research Department, Naval Weapons Center, China Lake, CA 93555. Obtain the directions for making a successful cold fusion cell and the directions for collecting and measuring effluent gases. Then replicate the results. See *Fusion Facts*, February 1991, page 10 for a review of Miles et al, J Electroanal Chem, **296**, 1990, 241-254. In this article the authors tell how they progressed from negative results to positive measurements of excess heat by increasing the diameter of the Pd cathode to 0.635 cm. They reported success in stopping and restarting cells.

As the work of Miles and others at the Naval Weapons Center (or similar work) is repeated and reported then the following can be stated:

1. Cold fusion is a scientific reality.

2. There is an experimental basis for repeatability and therefore, for parametric studies (to improve performance).

3. A strong contribution is made to theory development.

4. The nuclear reaction(s) to be further studied are those that involve the production of ^{4}He. Two reactions to be considered are:

d + d --> ^{4}He and
^{6}Li + d --> ^{4}He + ^{4}He.

In other words, the predominant cold fusion reactions are aneutronic (produce no neutrons) and atritonic (produce no tritium).

5. Deuterium fusion branching ratios in a Pd lattice are dramatically different than in high-temperature plasma physics. [The leaders of the American Physical Society owe Drs. Pons and Fleischmann (and others) a strong apology. Ed.]

SURFACE OR BULK REACTION?

The evidence from this work suggests that the helium is produced near the surface of the Pd cathode. Otherwise much of the helium would remain trapped in the lattice. It is appropriate, of course, to submit a spent Pd cathode for analysis for helium. Other experiments in which light water was added to working cold fusion cells has given us mixed signals. Different experimenters have reported immediate (surface effect) or slow quenching (bulk effect) of the excess heat.

We, who love to predict (and are sometimes wrong), suggest that nuclear reactions are taking place in the surface and in the bulk of the Pd cathode depending on subtle and, as yet, unexplained experimental variables. Therefore, **we predict,** the best cold fusion, heavy water cells will provide excess energy from both surface and bulk reactions.

Note: This preliminary paper is expected to be followed by results from a planned operation of a closed cell in which much of the effluent gases are recombined.

IN TRIBUTE

The Robert A. Welch foundation and the ONT/ASEE post-doctoral fellowship program are to be commended for their support of this important contribution to the understanding of cold fusion.

Dr. Miles and his associates have labored diligently from early failures through to current successes. They have demonstrated American science at its best. This quest for the replication of cold fusion brings to mind the following: *"On the Plains of Desolation bleach the bones of countless thousands, who at the Dawn of Victory, sat down to rest, and resting - died." Anon.*

It is a great tribute to our Armed Forces and their laboratories that this significant achievement has been made in a Naval facility. In contrast the Department of Energy recently announced that no funding has been requested for cold fusion because it was not deemed to be an alternative energy source within a 30 to 40 year time period [5]. Let's prove the advisors to DoE wrong!

[1] Hal Fox, "Cold Fusion Successes, Achievements, and Primary Sources", *Fusion Facts*, Vol 1, No 12, June 1990, page 5, 31 refs.

[2] D. Cravens, M. Dehn, S. Faile, & H. Fox, "Survey of Nuclear Byproducts", *Fusion Facts*, Vol 2, No 4, Oct 1990, pp 14-26, 112 ref from 16 countries. [Does not include papers reporting only on excess heat.]

[3] M.H. Miles, K.H. Park, & D.E. Stilwell (Naval Weapons Center, China Lake), "Electrochemical Calorimetric Studies of the Cold Fusion Effect", *First Annual Conference on Cold Fusion - Conference Proceedings*, March 28-31, 1990, University Park Hotel, Salt Lake City, Ut., pp 328-334, 9 refs.

[4] M. H. Miles, K.H. Park, & D.E. Stilwell, "Electrochemical calorimetric evidence for cold fusion in the palladium-deuterium system", *J. Electroanal Chem*, Vol 296 (1990), pp 241-54, 11 refs. [See review in *Fusion Facts*, Feb 1991, pg 10.]

[5] "Cold Fusion Spark Almost Dead at DoE", *Salt Lake Tribune*, Mar 7, 1991.

B. REPEATABILITY OF COLD FUSION

A REVIEW OF WHAT WE HAVE LEARNED ABOUT REPLICATION OF COLD FUSION CELLS
By FF Staff.

The following facts about replication are presented for review with our interpretation. The experimental facts are considered accurate. The interpretation is subject to further experimental or theoretical developments.

Replication is difficult.

FACT: Many experimenters have demonstrated that it is not easy to reproduce the Pons-Fleischmann cold fusion electrochemical cell and obtain excess heat.

INTERPRETATION: The experiment may appear simple to perform but has difficult or subtle aspects that are not well understood.

All original results have been replicated by many.

FACT: One or more of all experimental results originally reported [1] for cold fusion have been replicated by over 135 laboratories [2,3] including the replication of the measurement of neutrons (the most difficult), the production of tritium (frequency of occurrence about one million times more often than neutrons), and obtaining excess heat as steady-state or in bursts. However, nearly all successful experimenters have had problems in reproducing their own successes.

INTERPRETATION: The experiment is difficult to replicate even under the (presumably) same conditions. These results are similar to the early days of solid-state semiconductor research, especially when working with yields of integrated circuits. Therefore, there may be some minute contamination that can harm or help the experiment. The lack or presence of such a poison or promoter can significantly affect the results.

Alter the Electrolysis Process

FACT: Some have achieved (or reported that they have achieved) essentially the same results using the same or similar cells. For example, Yang (et al.) [4] at National Tsing Hua University in Taiwan observed that the level of excess heat produced appeared to decrease with time. They elected to ramp up the cell voltage (input power) by one volt per day during the same hour each evening for a number of days. The results were beneficial and they had both excess heat and tritium production from the first six cells.

INTERPRETATION: It appears that in the cell configuration, there was a barrier being slowly built up on the surface of the palladium cathode and that the raising of the voltage was sufficient to overcome the daily surface buildup.

Use of Larger Cathodes

FACT: Miles et al. [5] have reported the lack of positive results when using palladium cathodes having a diameter of 0.14 cm. and an area of 2.64 sq cm. When essentially the same experiment was tried using Pd rods with a diameter of 0.635 cm and an area of 2.64 sq cm, the results were positive.

INTERPRETATION: Use larger Pd cathodes. A possible explanation is that the effect depends on the geometry of the anode/cathode which in turn affects some important factor (such as electromagnetic field strengths) that are not easily achieved in a thin wire.

Try Different Electrode Shapes

FACT: Huggins at Stanford [6] had a series of modest results using a "fat dime" shaped Pd cathode. Excess heat was produced over long periods of time. Huggins also suggested the use of molten salts. Liebert and Liaw (both former students of Huggins) invented a molten salt approach. Excellent results were achieved in at least one Pd anode configuration (excess heat up to 16 times the input power) but replication has been a problem.

INTERPRETATION: The configuration of an electrochemical cell is important. Huggins used a "fat dime" cathode and Liaw et al. [7] used a different electrochemical approach using molten salts and LiD as the compound to be separated into fuel constituents, thereby using the Pd as an anode.

Producing Tritium Repeatably.

FACT: Claytor [8] at Los Alamos uses a stack of silicon and palladium disks immersed in deuterium gas and activated with bursts of high voltage. The results are the repeatable production of a nuclear byproduct (tritium) using a considerably different cold fusion cell.

INTERPRETATION: Nuclear effects can be replicated in a Pd-deuterium environment. Electrochemical cells using heavy water are not the only way to support nuclear reactions in a Pd lattice.

Controlling Nuclear Reactions.

FACT: Bockris [9] reported that McKubre has achieved repeatable results with at least one cell configuration. Although unpublished, it has been stated that McKubre has been able to increase/decrease the production of excess heat by changing the current through the cell.

INTERPRETATION: Control of a cell is achievable. Several experimenters have reported (privately or in public) that they have achieved controllability of an operating cold fusion cell. Others have been Liaw et al., Bush, Schoessow, and Noninski (see below).

Summary.

Huggins and others who have had consistent success in reproducing their own experimental results have deviated from the standard Pons-Fleischmann cell configuration. The hints are: Use larger diameter versus small diameter (within reason as the loading time before excess heat is produced may be a strong function of the size of the cathode). Use different shapes for the cathode - knowing

that the classical Pons-Fleischmann configuration has been quite unproductive in terms of repeatability. Observe all of the teachings of skilled electrochemists and materials scientists in terms of cleanliness, promoters, poisoners, electrolyte combinations, etc. but take lessons from those who have a proven track record (especially Huggins, Bockris, Noninski, Liaw, Bush & Eagleton, Miles, and other successful experimenters).

Take advantage of the experimental findings of others, but be skeptical. No one has all of the answers yet, or if they do they haven't shared their methods. The difficulty in replication leads to the tendency to "lock in" on the first thing that works. Recognize that we must define and use a repeatable starting point before we can plan and work experiments that will lead to improvements.

Electrode Preparation.

Over one hundred experimental groups have had some degree of success with measuring nuclear byproducts from a cold fusion electrochemical cell. Something works. Most successful experiments have been performed using a palladium cathode, a platinum anode, 99.5% pure heavy water, and a 0.1 Molar solution of lithium deuteroxide (LiOD). Many of the papers publish the source for their reagents and metals used and provide specs on the purity.

The electrode preparation is critical. One of the best papers to discuss the importance of electrode preparation is Huggins [10]. Essentially it is important to use the "correct" purity of palladium obtained from a source that is known for providing "working" electrodes.

There have been rumors that one supplier has provided palladium containing helium. There are rumors that alpha-particle bombardment (helium ions) of the palladium surface is an effective treatment. Others have been successful in using reverse current through the palladium to "de-plate" surface contamination. At least one successful experimenter uses a white glove approach in handling the palladium electrodes and observes a specific annealing time and temperature following by surface treatment.

Huggins [10] teaches that very small levels of contamination can cause large changes in the activity of the electrode. Those familiar with the strong effects of very small amounts of selected elements in a semi-conductor will exercise great caution in experimental procedures involving cathode preparation.

Use the experience of experimenters who have had successes in repeatability. Most are willing to share their experience with other scientists. They may assume, in their written reports, that the reader has electrochemical or materials science skills and yhey may not write down all of the steps they used. Few are "skilled in the art".

REFERENCES

[1] M. Fleischmann, S. Pons, and M. Hawkins, "Electrochemically induced nuclear fusion of deuterium." *J. Electroanal. Chem*., 261, pp 301-308, and erratum, 263, p187 (1989).

[2] Hal Fox, "Cold Fusion Successes, Achievements, and Primary Sources", *Fusion Facts*, Vol 1, No 12, June 1990, page 5, 31 refs.

[3] D. Cravens, M. Dehn, S. Faile, & Hal Fox, "Survey of Nuclear Byproducts", *Fusion Facts*, Vol 2, No 4, October 1990, pg 15-26, 112 refs. [This survey does not include papers reporting only excess heat production.]

[4] C.S. Yang, C.Y. Liang, T.P. Perng, L.J. Yuan, C.M. Wan, and C.C. Wan (Materials Science Center, National Tsing Hua University, Hsinchu, Taiwan, 30043, R.O.C.), "Observations of Excess Heat and Tritium on Electrolysis of D_2O", *Special Symposium Proceedings - Cold Fusion*, World Hydrogen Energy Conference #8, Honolulu, Hawaii, July 22-27, 1990, pp 95-106, 11 refs.

[5] M.H. Miles, K.H. Park, & D.E. Stilwell, "Electrochemical Calorimetric Evidence for Cold Fusion in the Palladium-Deuterium System," *J. Electroanal Chem.* **296**, 1990, pp 241-254.

[6] M. Schreibner, T.M. Gur, G. Lucier, J.A. Ferrante, J. Chao, & R.A. Huggins, "Recent Measurements of Excess Energy Production in Electrochemical Cells Containing Heavy Water and Palladium", The First Annual Conference on Cold Fusion Conference Proceedings, March 1990, pp 44-56, 7 refs.

[7] B.Y. Liaw et al., "Elevated Temperature Excess Heat Production Using Molten-Salt Electrochemical Techniques", *Special Symposium Proceedings - Cold Fusion*, World Hydrogen Energy Conference #8, Honolulu, Hawaii, July 22-27, 1990, pp 49-60, 10 refs. [Also printed in full in October 1990 *Fusion Facts.*

[8] T. Claytor (LASL), "Tritium Generation in PdSi Systems; Gas and Liquid Analysis Facilities for Detection of Tritium", Proceedings of Anomalous Nuclear Effects in Deuterium/Solid Systems, B.Y.U., Oct 22-24,1990.

[9] John Bockris (TAM), "Cold fusion II: the story continues", *New Scientist*, 19 Jan 1991, pp 50-53.

[10] R.A. Huggins (Stanford), "Fundamental Considerations Relating to the Electrochemical Insertion

of Hydrogen and Palladium into Mixed Conductors", *Special Symposium Proceedings - Cold Fusion*, World Hydrogen Energy Conference #8, Honolulu, Hawaii, July 22-27, 1990, pp 181-205, 82 refs.

C. NEWS FROM THE U.S.

BOSTON - PROPOSED USE OF ULTRASOUND

P.H. Fang (Boston College, Mass.), "Deuterium Fusion Through Nonequilibrium Induction," *Fusion Technology* 19, March 1991, pp 369-370.

ABSTRACT

A deuterium fusion system is proposed that is based on the induction of fusion through a nonequilibrium thermodynamical configuration. Mechanical excitation using ultrasound is applied to (a) a palladium electrode with deuterium-containing liquid, (b) a mixture of palladium powder and deuterium-containing liquid, and (c) a system of palladium and a highly compressed deuterium gas that approximates a deuterium solid. The ultrasound, when coupled with the medium of these systems, instantaneously creates a high temperature and pressure that would induce fusion between deuterons.

EDITOR'S COMMENTS

In light of successful experiments in which nonequilibrium conditions were present (due to temperature cycling in gas-loading, and hysteresis or varying conditions in electrolysis), the authors propose that experiments use ultrasound to increase collisions. It should be pointed out, however, that the efficacy of such a procedure may be limited in D_2O by the boiling point of the heavy water, and in any Pd system by the decrease in deuterium solubility at similar temperatures.

CAL POLY - TRM THEORY UPDATE

Robert T. Bush (Cal. State Polytechnic U), "Cold 'Fusion': The Transmission Resonance Model Fits Data on Excess Heat, Predicts Optimal Trigger Points, and Suggests Nuclear Reaction Scenarios," *Fusion Technology* 19, March 1991, pp 313-356.

EDITOR'S COMMENTS

A preprint of this paper was reviewed in the October 1990 issue of *Fusion Facts*, p. 27, by permission of the author and journal. Similar results were also presented by Dr. Bush at the Anomalous Nuclear Effects conference in Provo, Utah in October 1990, reviewed in the November 1990 *Fusion Facts* issue. Additional information on the effect of stoichiometry is also noted in letters by Dr. Bush in the February 1991 issue and in Section E of this issue.

As previously indicated, the TRM model calculates large increases in tunneling of bosons such as deuterons through a regular series of Coulomb barriers in a lattice when certain sets of conditions are met. In particular, in experiments such as gas-loading, a certain sequence of temperatures is indicated to be optimal for any alloy, and in an electrochemical cell the positions of such optima will also be strongly affected by current density and by cathodic overvoltage (a function of the electrode surface characteristics).

Thus, the model makes the unique prediction that if two of these three parameters are held constant and the third is varied, a series of maxima in the fusion rate will be measurable. In appropriate circumstances, the excess heat can therefore be increased by *decreasing* the temperature or current density. Also, the maxima will exhibit a fractal pattern, with the height (fusion rate) and width increasing as the parameter is increased, up to a certain point at which the output will drop to zero. Maxima are predicted to be asymmetric, with an almost linear increase to a local maximum quickly followed by a sharp drop, as plotted in the article. (N.B.: Controlling these parameters is not as simple as it might sound; for example, increasing current density will tend to increase the cell temperature, and changing the cell temperature may affect the overvoltage.)

As previously discussed, data fitting this pattern has been reproduced in experiments by Dr. Robert Eagleton, also of Cal Poly, and certain other laboratories have subsequently expressed interest in replication. It should be noted that experiments such as described above would need to satisfy three requirements in order to document the diagnostic fractal pattern. First, conditions must be within appropriate ranges in which reactions of the type being measured will occur, and other factors which could cause reproducibility problems must not prevent reaction or result in erratic behavior. Second, a sufficiently close spacing of experimental data points in the region of a maximum-minimum pair is necessary to define the narrow minimum; otherwise the general upward trend will merely give the appearance of a straight line with increased random scatter. Third, the remaining parameters must remain sufficiently constant during the test. In this respect, the overvoltage can be expected to prove a particular problem. Since overvoltages will drift with time due to progressive changes in the electrode surface characteristics, experiments must either possess sufficiently fast response times to allow scanning up and down through a sufficient portion of the curve before the curve shifts, or else temperature and current density must be held constant as the overvoltage is allowed to shift over the course of a much longer experiment.

In ordinary cold fusion experiments, changes in overvoltage could give both a steadily changing (increasing or decreasing) excess output and a pattern of bursts changing in size and spacing in the same fashion. A series of bursts superimposed on a gradually increasing level of excess heat has, in fact, been noted in experiments by Drs. Fleischmann and Pons, *J.Electroanal. Chem.* 287, pp 293-348. It is also noted that gradual overvoltage changes could also account for experiments in which appearance of an effect occurred only after prolonged electrolysis, and explain how this could also depend on the solution impurities and anode composition.

CALIFORNIA - NEW THEORY ADDITION
Courtesy of Dr. Robert T. Bush
California Polytechnic University - Pomona

See Section E, Short Articles for an explicit formula for power output from cold fusion from Dr. Bush.

FRESH WATER NEEDED!
Courtesy of Avard F. Fairbanks

Mark D. Uehling, "Salt Water on Tap", *Popular Science*, April 1991, pp 82-85.

ABSTRACT

As drought and irrigation take their toll, engineers are devising new methods for desalting seawater and agricultural runoff.

EDITOR'S COMMENTS

Because of the rapid advances being made in cold fusion, we should look at some of the potential applications. This article reviews the needs and some of the existing technology being used or developed for desalination. One of the more important comments is the following: "Besides hydraulic mishaps, desalination plants in much of the world are plagued with exorbitant energy bills."

Fusion Facts would like to hear from any reader who has compiled the latest information on the energy costs of producing fresh water from sea water. A conservative estimate of the cost of cold fusion energy (with projected inefficiencies in deuterium conversion) is five cents per energy equivalent of one gallon of fuel oil. By comparing a variety of methods of desalting sea water, it might be that some technologies (such as direct distillation) would be economically feasible and more reliable than current systems.

TEXAS A&M - REVIEW

John Bockris and Dalibor Hodko (U of Texas), "Is There Evidence for Cold Fusion?", *Chemistry & Industry*, November 5, 1990, pp 688-692.

EDITOR'S COMMENTS

This review article updates the material in previous reviews by Dr. Bockris, and includes an earlier tabulation prepared by Dr. Fritz Will (National Cold Fusion Institute) of 79 laboratories reporting cold fusion evidence, with references [see also *Fusion Facts* October 1990]. Note that this paper was prepared before the October 1990 conference at Brigham Young University, and thus the current number of successful groups is greater. The article also includes two graphs which show particularly dramatic bursts of heat and production of tritium.

UNIVERSITY OF CHICAGO

COLD FUSION PER ENCYCLOPAEDIA BRITANNICA 1991 BOOK of the YEAR

Andrew T. Boothroyd, "Physics", 1991 Britannica Book of the Year, page 278.

The summary of the advances made in cold fusion as reported by one of the world's most prestigious encyclopedias states:

"Occasionally, respected scientists announced discoveries of new and unexpected phenomena that later, after attempts at independent confirmation, turn out to be false. As recently as 1989, for example, cold (room-temperature) fusion was reported, bringing dreams of cheap, limitless energy, but a year later it was generally regarded as nonexistent."

THIS EDITOR'S COMMENTS

We will send Boothroyd a copy of *Fusion Facts*.

UNIVERSITY OF ROCHESTER - NEUTRON AND GAMMA DETECTION

Jacob Jorne (U of Rochester), "Neutron and Gamma-Ray Emission from Palladium Deuteride under Supercritical Conditions," *Fusion Technology* 19, March 1991, pp 371-374.

ABSTRACT

Palladium is exposed to pressurized deuterium gas at 60 atm and 198 K and the temperature is cycled up to 593 K, beyond the critical point for palladium deuteride. Two neutron and gamma-ray counters, located near the pressurized vessel, show evidence of excess neutrons and gamma rays beyond the background level. Similar experiments with an empty cell or with a hydrogen-palladium cell show no excess in neutrons and gamma rays beyond the background levels. If the excess in neutrons is due to fusion, a corresponding fusion rate of 10^{-21} fusion/d-d per sec can be estimated, which is comparable to the rate of 10^{-23} reported by Jones et al. for electrochemically induced fusion.

EDITOR'S COMMENTS

Although phase transitions of the sort typically induced during temperature cycling in gas-loading experiments (such as the transition in Ti at -30 C) were eliminated, neutron and gamma emission were observed as the sample was heated above 500 K. This temperature is near the critical temperature above which alpha Pd deuteride cannot exist, and the author suggests that large fluctuations in density (i.e. in local loading) occurring under these conditions may be responsible. The fact that a portion of the Pd was under stress was also noted.

In addition, another experiment was noted in which a particularly high D/Pd ratio was measured in a sample which had not passed through a phase transition during loading. However, reference to this paper [A.C. Ehrlich et al., *Fusion Technology* 16, p 529] reveals that the elimination of the alpha-beta phase transition occurred because loading was not begun until the sample has been heated to over 300 C. Since such a procedure was not followed in the present paper, it is not clear that an alpha-to-beta phase transition would not have occurred during initial loading in the present experiment. Furthermore, the previous experiment thereafter decreased the temperature and used electrolysis to reach the high loading reported.

As the critical temperature of 568 K was approached, the fast neutron count rates in two NE213 detectors (total efficiency 1%) increased by 0.13 counts/sec. This represented an increase of approximately 45-fold or 140 standard deviations in the low-background counter, and approximately two-fold in the other counter. The gamma count rate which had been stable at 72-74 counts/second increased to 77-81 counts/second.

U.S. NAVY LABORATORY & U of TEXAS
Courtesy of Drs. Miles & Bush
See lead article page 1.

D. NEWS FROM ABROAD

BULGARIA - CALORIMETRY

V.C. Noninski and C.I. Noninski (Lab. for Electrochemistry of Renewed Electrode-Solution Interface, Sofia), "Determination of the Excess Energy Obtained During the Electrolysis of Heavy Water," *Fusion Technology* 19, March 1991, pp 364-368.

ABSTRACT

The total heat balance during the electrolysis of D_2O with a palladium cathode is determined by placing the entire hermetically sealed electrolysis system (the electrochemical cell connected with a vessel of varying volume) in an isoperibol calorimeter. Significant excess power density (excess specific rate of heating) is obtained even though a palladium cathode of thin wire (0.05-cm diam) is used, in which case a relatively low value of excess energy is expected. The method and arrangement applied remove the main causes of inaccuracies in determining the excess energy. Thus, the possibilities of using this energy seem to be greater than some researchers are inclined to consider.

EDITOR'S COMMENTS

The method discussed attempts to eliminate a variety of potential sources of error identified in previous calorimetry experiments. The cell is entirely submerged in a stirred water bath enclosed in a Dewar vessel. In addition, the evolved gases are collected in a balloon submerged in the bath, thus minimizing errors in open-cell calorimetry due to the heat of evaporation of the water with which these gases may be saturated, and to the possibly higher temperatures of the gases. In addition, the measured increase in volume of the balloon is used to confirm that measurable recombination of the gases does not occur. However, it would appear that such an approach could limit electrolysis times, once the balloon was connected.

An open rather than closed cell was used in the belief that it could result in higher deuterium loading of the Pd. Excessively rapid recombination in closed cells, it was argued, could decrease the amount of D_2 in the solution surrounding the cathode.

Comparison of the temperature increase of the water in the calorimeter with that produced by a resistance heater indicated 0.1 to 2.6 W of excess heat (1.66-41.4 W/cm^3 Pd) during 3-minute measurements at relatively low current densities (typically 26 mA/cm^2). This corresponded to at least 7 times the energy which could be produced by

recombination, but only up to 20% greater than the electrolysis input power (presumably because of the high resistance of the electrolyte). Steady-state conditions (constant loading) are inferred from the match between the volume increase of the balloon and the volumes of D_2 and O_2 expected to be generated by the measured current in the absence of recombination.

This experiment differs from most previous experiments in several ways. The electrolyte contains 0.01 M K_2SO_4, rather than 0.1 M LiOD, in D_2O. The lower concentration and larger ionic radii would have resulted in much higher cell resistances, such that 40 V were required for even a low current density of 26 mA/cm^2). In addition, no Li is present. The cathode is also unusual in that it is not rod-shaped, but folded in a zigzag manner to form a bundle. Finally, it is inferred from the paper that interruption of the electrolysis current was necessary for approximately 10 minutes prior to the start of each measurement. If the experiment been conducted at the higher current densities and thus higher loadings used in most other experiments, the resulting drop in loading during this time could have been significant, thus complicating analysis of the results by altering gas volumes and heat balance. Nevertheless, this is one of the best arrangements for calorimetry that we have seen that could easily be adapted for use in a corporate or university laboratory.

GERMANY

ELECTROCHEMISTRY & SEMICONDUCTORS

H. Gerischer (Fritz Haber Institut, Berlin), "The Impact of Semiconductors on the Concepts of Electrochemistry", *Electrochimica Acta*, Vol 35, No 11/12, pp 1677-99, 1990, 129 refs.

AUTHOR'S ABSTRACT

The study and kinetic interpretation of electrode reactions was, from the early years of electrochemistry, dominated by processes occurring at electrodes with metallic conductivity. Only since the late 1950s and early 1960s has it been realized that semiconductor electrodes behave differently in many respects and offer new insights into the role played by the electronic properties of a solid in its electrochemical reactivity. The investigation of semiconductor electrodes has intensified the link between electrochemistry and solid state physics, has created a close connection to photochemistry and has profoundly improved the understanding of interfacial reactions. Selected examples are presented in this paper.

AUTHOR'S INTRODUCTION

For a long time in electrochemistry, the electrode was considered only as a source, or a sink, of electrons provided by an electronic conductor with low resistivity. The individual properties of the electrons in these conductors were not considered. The chemical reactivity of the electrode surfaces was evident, in electrocatalysis or in corrosion, for example, but could only rather vaguely be linked to the electronic properties of the substrate. That this has changed today is, in my opinion, to a large extent a consequence of the interest shown by electrochemists in the field of semiconductors. Semiconductor problems also stimulated many physicists to deal with electrochemical questions and provided a link between electrochemistry and photochemistry. In this paper, I shall discuss several areas, in which semiconductors opened new perspectives in electrochemistry, and for this presentation I have chosen the four principal areas as follows:

1. The electrical double layer

2. Charge transfer reactions
   a. Electron transfer
   b. Ion transfer

3. Excited electronic states and reactivity
   a. Excitation of the solid
   b. Excitation of redox species at the interface

4. Passivity and corrosion.

AUTHOR'S CONCLUSIONS

The examples given in this paper should have demonstrated in how many respects the study of semiconductor electrodes has affected and widened the concepts of electrochemistry. This is certainly a small contribution in comparison to the impact of semiconductors on the technology of electronic measuring techniques, of communications and computation, from which electrochemists have equally profited. These new concepts revitalized the traditional science of electrochemistry in many aspects and stimulated the interest of colleagues from solid-state physics and from photochemistry in electrochemical questions. Today, semiconductor electrochemistry is a basic part of electrochemistry and can be very helpful to our colleagues from related areas in understanding difficult interdisciplinary problems in which electrochemistry is involved. This is also a challenge in the education of our students and should find an adequate treatment in the textbooks of electrochemistry.

EDITOR'S COMMENTS

The received doctrine in several segments of physics and chemistry are being challenged by new experimental evidence in cold fusion. Because cold fusion appears to

be a combination of electrochemistry and solid-state physics, *Fusion Facts* has long been a proponent of a closer mingling of expertise between the cold fusionist and the solid-state physicists. We chose to include this article to whet your appetite for more interdisciplinary information that may help solve some of the problems in cold fusion.

NEW FROM ITALY
Courtesy of Prof. Giuliano Preparata

T. Bressani, E. Del Giudice, & G. Preparata, "What Makes a Crystal Stiff Enough for the Moessbauer Effect?", Submitted for publication. Author's MITH 90/4, 9 manuscript pages, 12 ref.

AUTHORS' ABSTRACT

We show that the difficulties of interpreting the Moessbauer effect as a coherent lattice (phononic) phenomenon can be surmounted by relating it to a superradiant behavior of the plasma of nuclei of a crystal. As a result a generalized Debye-Waller factor is seen to emerge for determining the intensity of the effect.

AUTHORS' CONCLUSION

We conclude by stressing that the mysterious nature of the Moessbauer effect, that engenders a strong violation of "asymptotic freedom" in a crystal, has been resolved by assuming that the plasma of nuclei undergoes a superradiant dynamical evolution. We believe that this is a further piece of the jigsaw puzzle of coherent electromagnetism in condensed matter that goes into place.

EDITOR'S COMMENTS

Several theories relating to cold fusion use properties of the crystal lattice including coherence, superradiance, and inverse Mossbauer effect. Some of our readers, including the editor, can benefit by a better understanding of these complex physical principles. This paper and the following paper provide an insight into the physical principles of the crystal lattice.

As the paper reviews, the Mossbauer Effect is normally explained with the idea that the recoil from the decay of a single nucleus is absorbed by a large number of nuclei of the crystal. This process is explained by invoking quantum mechanics (assuming that the lattice nuclei do not become excited) and a coherent process. If it is assumed that the communication among lattice nuclei is by phonons, then the authors question whether the speed of sound is sufficient to inform the lattice of the decay event so that the lattice can provide collective recoil.

The authors show that the phonon assumption is not valid. The communication among the lattice nuclei would require electromagnetic speeds (not sound speeds) to support the Mossbauer effect. The authors develop a modified Debye-Waller equation which does support the observed Mossbauer effect.

Their collective efforts are not in accord with "received doctrine" and is about as readily acceptable among some of the scientific fraternity as cold fusion. If you are interested in the developing theory of cold fusion, we recommend your study of this paper. For further information contact either Prof. Giuliano Preparata or the *Fusion Facts* staff.

FROM ITALY - MORE MOSSBAUER
Courtesy of Dr. Giuliano Preparata

Giuliano Preparata (Dept Physics, U of Milano), "Do We Understand the Moessbauer Effect?", Presented at the VII Summer Course in Nuclear Physics, L'Aquila, Italy, July 1990. Author's manuscript MITH 91/7. 10 manuscript pages, 9 refs.

AUTHOR'S ABSTRACT

The usual explanation of the Moessbauer effect is challenged on the basis of present understanding of condensed matter physics. It is argued that the effect represents a strong case in favour of superradiant interactions among the atomic nuclei.

AUTHOR'S CONCLUSION

We may thus conclude that superradiant behavior has provided us with an explicit mechanism to violate the Asymptotic Freedom property of the short-range electrostatic interaction. Also, the difficulty of the Heisenberg principle is beautifully overcome by recognizing that the velocity of propagation of the superradiant interaction is of the order of $c = 10^{10}$ cm/sec, and not V_S approx $= 10^6$ cm/sec. The Moessbauer effect can then be considered as one of the most significant pieces of evidence in favour of Superradiance.

EDITOR'S COMMENTS

This companion paper to the one reviewed above is deemed to be an important paper both to help the reader understand the Mossbauer effect but also because of its mathematical similarity to Prof. Preparata's theory in explaining cold fusion.

The author states, "The real puzzle of the Moessbauer effect is thus the extreme stiffness required of a crystal in

order to support recoilless emission and absorption. A stiffness that makes it possible for nuclear processes ... to be deeply affected by the crystal matrix in which they take place. Incidentally, ... a similar puzzle appears to be the reason why the vast majority of physicists have turned their backs to the strange phenomena of cold nuclear fusion."

Preparata shows that the Debye solid (which accounts for a large number of crystal properties) depicts the crystal as a mathematical lattice around which nuclei perform coupled harmonic oscillations that can be described by quantum fluctuations, the phonons. Preparata shows that a mathematical lattice cannot describe a system of physical nuclei that fluctuate as free quantum mechanical particles at scales smaller than a few Angstroms.

Preparata then shows that the concepts of superradiance (in which the nuclei of a crystal are modeled as a plasma) can be used to modify the usual Debye-Waller factor and suitably explain the Mossbauer effect. One of the computed results is the number of nuclei in a coherence domain which is found to be about 10^{10}.

Copies of this paper may be obtained from the author or, by permission from the author, through *Fusion Facts* staff.

INDIA - TRITIUM IN Ti PLASMA FOCUS

R.K. Rout, M. Srinivasan, A. Shyam and V. Chitra (Bhabha Atomic Research Centre), "Detection of High Tritium Activity on the Central Titanium Electrode of a Plasma Focus Device," *Fusion Technology* 19, March 1991, pp 391-394.

ABSTRACT

A 2-kJ Mather plasma focus device is used to deuterate the top end surface (or tip) of its central titanium electrode to investigate the occurrence of anomalous nuclear reactions in the context of the "cold fusion" phenomenon. The tip of the central titanium electrode is found to develop at least a few tens of microcuries of tritium after several plasma focus discharges. Neither the tritium impurity level in the deuterium gas used in the experiment nor the tritium branch of the d-d reactions that are known to occur in plasma-focus devices can account for such activity in the electrode. Anomalous nuclear reactions in the deuterated titanium lattice appear to be the most probable source of this high activity.

EDITOR'S COMMENTS

This experiment was also described by Dr. Srinivasan at the Anomalous Nuclear Effects Conference held in October 1990 [*Fusion Facts*, November 1990]. As a 12 KV discharge in deuterium gas is involved, significant thermonuclear fusion may be expected due to accelerated deuterium ions, and indeed approximately 10^7 neutrons per discharge were measured by neutron activation of silver. However, the highest tritium activity measured represented over 10^6 times more tritium atoms than the number of neutrons measured.

JAPAN - NEUTRON BURSTS

Tsutomo Sato, Makoto Okamoto, Poong Kim, Yasuhiko Fujii (Tokyo Institute of Technology) and Otohiko Aizawa (Musashi Institute of Technology), "Detection of Neutrons in Electrolysis of Heavy Water," *Fusion Technology* 19, March 1991, pp 357-363.

ABSTRACT

Neutron measurements are conducted during heavy water electrolysis in a glass cell equipped with a palladium cathode and a platinum anode set in separate electrode compartments. The electrolysis shows neutron emission peaks at 5 h (runs 1 and 2) and at 20 h (run 3) after start-up. The neutron emission peaks were clearly detected by independent A and B ^{3}He counter channels; the peak values exceed 3 sigma. The neutron emissions are confirmed to occur in bursts.

EDITOR'S COMMENTS

This experiment preloaded the cathode with deuterium using high-pressure D_2 gas, in the hope that effects could therefore be seen sooner after the start of electrolysis. This assumption may not be valid if the effect of long electrolysis time is to cause a necessary change in the electrode surface conditions. The maximum count rate was a few hundred counts per 2000 seconds, seven standard deviations above and slightly over twice the background. In addition, bursts of up to 29 neutrons in 100 microseconds were also detected, compared with a maximum burst size of 3 in a background run apparently one-third as long.

JAPAN - THEORY AND NEUTRON OBSERVATIONS

Akito Takahashi, Toshiyuki Iida, Fujio Maekawa, Hisashi Sugimoto and Shigeo Yoshida (Osaka U), "Windows of Cold Nuclear Fusion and Pulsed Electrolysis Experiments," *Fusion Technology* 19, March 1991, pp 380-390.

ABSTRACT

Based on the electron screening effect and the excitation of deuteron harmonic oscillators in a palladium lattice, possible explanations of cold fusion phenomena and the

possibility of nuclear heating are discussed. A narrow window is proposed to reach the approximately 10 W/cm^3 required nuclear heating for three-body fusion by a hypothetical excitation-screening model. A relatively wide window is feasible to reach a few fusion events per second per cubic centimeter under the nonstationary conditions of deuteron charging and discharging. Cold fusion is not feasible under stationary lattice conditions.

To confirm the cold fusion phenomena, a heavy water electrolysis experiment is carried out using biased-pulse electrolytic currents, in order to enhance the detection of cold fusion events during charging and discharging of deuterons. A cross-checking system consisting of a recoil-proton scintillation detector and a ^{3}He thermal neutron detector is used to determine the patterns of neutron emission over time. To determine the energy of the emitted neutrons, the pulse-height spectra of the recoil-proton detector are monitored. For a deuterium charging time of 300 h, neutron yields of 1 to 2 neutrons/sec per cm^3 are obtained for time intervals of 60 to 200 h. From the recoil-proton spectra, it is confirmed that 2.45-MeV neutrons from the D(d,n)^{3}He fusion branch reaction are emitted. The observed time patterns of neutron emission suggest the existence of cold fusion under deuterium charging and discharging.

EDITOR'S COMMENTS

Calculations are presented indicating the possible enhancement in the d-d fusion rate due to higher deuteron energy (on the order of eV) and charge screening approaches a limit of $10^{-12\text{-}13}$ fusions/second per deuteron (versus 10^{-150} fusions/second per deuteron in PdD under stationary conditions). Highly excited deuterium vibrational states (energy 0.6-1 eV, versus 0.06 eV for the ground state) are suggested to result in interactions of predominantly 3 or 4 rather than only 2 deuterons, due to the presence of both octahedral and tetrahedral sites, possibly leading to enhanced production of ^{4}He. Irradiation with photons of energy close to 1 eV is suggested to excite these vibrational states.

In the experiment, a pulsed current designed to cause net deuteron fluxes in and out of the cathode over 1/2 to 4 minutes was superimposed on a steady current to maintain high loading. (Although not noted in the paper, the limits between which the resulting loading would alternate will presumably both lie between the values resulting from prolonged electrolysis at the low and high currents.)

In an early experiment, the maximum increase in the ^{3}He detector count rate shown was 60% above background after correction for variations in the background; the same variations were also noted using the NE213 scintillation counter. In a later experiment, a 5-10% excess in 2-3 MeV neutrons was maintained over 3 successive weeks.

JAPAN - EUROPEAN PATENT

APPARATUS FOR COLD NUCLEAR FUSION
Courtesy Dr. J.O'M. Bockris

The following European Patent Application was filed on April 26, 1990 with priority dates of April 27, 1989 and December 12, 1989.

Title: Apparatus for cold nuclear fusion.

Applicant: Matsushita Electric Industrial Co., Ltd.

Inventors: T. Gamo, J. Niikura, N. Taniguchi, K. Hatoh, & K. Adachi.

Abstract: An apparatus for cold nuclear fusion and an electrode therefore are disclosed. The apparatus comprising a container for containing hydrogen isotopes in liquid or gas state and at least one element made of a hydrogen isotope occluding alloy such as Laves phase C14 type or C15 type alloy wherein hydrogen isotopes are occluded in the element in a high density and occluded hydrogen isotopes collide with each other.

SUMMARY OF THE INVENTION:

An essential object of the present invention is to provide an apparatus capable of causing nuclear fusion reactions at a low temperature.

Another object of the present invention is to provide an apparatus capable of causing nuclear fusion reactions in an electro-chemical process at a low temperature.

A further object of the present invention is to provide electrodes suitable for causing nuclear fusion reactions therein at a low temperature.

EDITOR'S COMMENTS ON APPARENT STRATEGY

The patent application lists 32 metal alloys that have a hydrogen to metal atom ratio of 1.0 or larger. It appears that this group took off immediately upon the announcement by Pons and Fleischmann with the strategy of claiming all hydrogen-accepting alloys. Data included in the patent shows that they have produced tritium and neutrons. These examples are used to support the claimed achievement for cold nuclear fusion.

It will be interesting to follow the progress of this application in view of similar features in the Pons-Fleischmann international patent application.

For those interested: This patent application can be obtained from the European Patent Office. The publication number is EP 0 395 066 A2.

UK - NEGATIVE PAPER

R.G. Keesing, R.C. Greenhow, M.D. Cohler (U of York, United Kingdom), and A.J. McQuillan (U of Otago, New Zealand), "Thermal, Thermoelectric, and Cathode Poisoning Effects in Cold Fusion Experiments," *Fusion Technology* 19, March 1991, pp 375-379.

ABSTRACT

An unsuccessful attempt to repeat the observations by Fleischmann and Pons of cold nuclear fusion in deuterium-charged palladium is reported; no excess heat is found, nor is any gamma or neutron activity identified. Peltier heating at the palladium/platinum junction is investigated, but no effects are seen; the possibility remains, however, that a large Peltier coefficient may arise for deuterium concentrations that render the palladium-deuterium semiconducting. Finally, the effects of poisoning the palladium with cyanide were investigated.

EDITOR'S COMMENTS

Among other points, this paper notes once again the importance of surface poisons in enhancing the absorption of hydrogen isotopes by metals [citing M. Enho, Comprehensive Treatise on Electrochemistry, Chapter 5, Plenum Press, New York, 1983]. It is noted that in addition to cyanide's presumably desirable action as a hydrogen evolution poison (increasing the cathodic overvoltage of the Pd), it will also enhance dissolution of Pt anodes and deposition of the Pt on the cathode. Although not noted in the paper, other anode materials which form strong cyanide complexes would be similarly affected. Thus in this experiment the cyanide was deposited directly on the Pd rather than introduced into the electrolyte.

E. SHORT ARTICLES

THE TRM VACANCY FRACTION

By Dr. Robert T. Bush (Calif Polytechnic University, Pomona, CA.)

The February issue of *Fusion Facts* [1] reported on recent theoretical work of mine to incorporate stoichiometry in a quantitative fashion into my TRM (Transmission Resonance Model) for cold fusion. {A full discussion will appear in the forthcoming proceedings of the October 1990 BYU conference on cold fusion.} The TRM [2] is significant in being the only theoretical model that provides a fit to calorimetric data on cold fusion. The model predicts a curious fractal *fine structure* that has been verified in our calorimetric research at Cal Poly, Pomona (Bush and Eagleton [3]). The recent work shows that the explicit dependence of the relative excess power formula in the TRM upon stoichiometry S (x was employed previously), can be included by multiplying by a factor of P_S where

$$P_S = \left(\sum_{n=1} n\, S^n\right) / \left(\sum_{n=1} S^n\right). \quad (1)$$

[Note: S can be considered to be the fraction of interstitial lattice sites occupied by a deuteron. Ed.]

The beautiful result is that a plot of P_S versus S yields a remarkable curve, shown in the Feb 1991 issue of *Fusion Facts* [1], which begins to rise steeply after about S = 0.65.

Subsequent to my letter [1] in the last issue, I received a phone call from Dr. Robert Bass in which he pointed out that P_S takes on the following very neat closed form expression:

$$P_S = 1 / (1 - S). \quad (2)$$

This is easy to derive from (1), since it can quickly be shown that

$$\sum_{n=1} S^n = S / (1-S). \quad (3)$$

I am grateful to Dr. Bass for this contribution, since it reveals a highly satisfying feature of the model; which is that the relative excess power is inversely proportional to (1-S). This term (1-S) I will name the "vacancy fraction". [The fraction of lattice sites **NOT** occupied by a deuteron.] This result is especially gratifying in view of the fact that we are all convinced of the significance of high loading in order to make cold fusion work.

[1] R.T. Bush, "Palladium/Deuterium Ratio - Theory", *Fusion Facts*, Vol 2, No 7, Feb 1991, p 24-5.

[2] R.T. Bush, "Cold 'Fusion': The Transmission Resonance Model Fits Data on Excess Heat, Predicts Optimal Trigger Points, and Suggests Nuclear Reaction Scenarios", *Fusion Technology*, Vol 19, No 2, March 1991, pp 313-356, 84 refs.

[3] To be published.

PRIMER: CHARGED PARTICLES, X AND GAMMA RAYS

by Michael Dehn, Associate Editor

RADIATION AND PARTICLES: PRODUCTION

Conventional fusion reactions are typically accompanied by either gamma radiation or energetic particles of characteristic energies, in such a fashion that both energy and momentum are conserved. For example, in the reaction d + d--> t + p (Q=4.03 MeV), the triton (with 3/4 of the total product mass) ordinarily recoils with 1.01 MeV of kinetic energy (1/4 of the total energy yield), while the proton (1/4 of the total mass) carries off the remaining 3.02 MeV (3/4 of the total). A similar inverse relationship between particle kinetic energy and particle mass occurs in other reactions with more than one product. Thus, in the reaction

d + d --> n + ^{3}He (Q=3.3 MeV),

the neutron carries off 2.45 MeV and the ^{3}He nucleus 0.82 MeV.

On the other hand, in the reaction

d + d --> ^{4}He + gamma (Q=23.85 MeV), or p + d --> ^{3}He (Q=5.49 MeV),

with only one product, the gamma carries off virtually all of the energy, and the He nucleus is almost stationary.

The proton, triton and ^{3}He nuclei in the d-d reaction are referred to as charged particles since their velocities are so high that they typically remain bare nuclei until slowed substantially by repeated collisions. Kinetic energy, KE, is related to velocity, v, according to the equation

$KE = 1/2\ m\ v^2$, where m is the mass.

Collisions of sufficiently energetic particles or gammas with other nuclei can trigger additional fusion reactions. For example, collision of 3-MeV tritons (tritium nuclei) with other deuterium atoms should result in d-t fusion, detectable by generation of 14-MeV neutrons, in a certain fraction of cases. Other nuclear reactions such as disintegration of fragile nuclei (deuterium, beryllium, uranium, etc.) are also possible [1].

Characteristic gamma radiation can also result from secondary neutron-induced nuclear reactions. Neutron absorption reactions are often much more likely after the neutrons have been at least partially "thermalized" or slowed by collisions (with collisions with light atoms being especially effective in such slowing). For example, hydrogen is the most efficient moderator (to moderate the speed), and also has a significant tendency to absorb the neutrons once slowed. In this n + p --> d reaction, a characteristic 2.22 MeV gamma ray is emitted which can be used as independent evidence of the neutron flux. For example, if the cell is immersed in a water bath, a significant fraction of the neutrons emitted by the cell, after moderated or thermalized by passage through several centimeters of ordinary water or longer distances of D_2O, would then be expected to undergo this reaction in the succeeding tens of centimeters of water [2]. In general, such neutron absorption reactions are referred to as neutron activation if (as is often the case) the nucleus formed subsequently decays by emission of a gamma ray of a characteristic energy.

A third source of gamma rays of characteristic energies results when certain elements are excited by collisions with sufficiently energetic charged particles, or by other gamma rays. In the case of Pd, approximately one conventional d-d fusion in 10^7 would be expected to excite even-atomic-weight isotopes (those with a significant "quadrupole moment"), giving rise to gamma radiation of 374, 433, 513 and 555 KeV [2,3].

Both gamma rays and charged particles can also generate X-rays of specific energies if they are energetic enough to eject electrons from inner shells of other atoms they strike. Transitions of outer electrons to fill these vacancies will then generate X-rays with wavelengths characteristic of the element struck. For example, electrons dropping from the L and M shells to fill K-shell vacancies in Pd will cause the emission of 21.175 KeV ("K-alpha") and 23.816 KeV ("K-beta") X-rays with K-alpha predominating, such that the average Pd K X-ray energy is close to 21 KeV. Pd L-shell vacancies can also give rise to far less penetrating 2.838 and 2.990 KeV "L" X-rays. In Ti, K X-ray energies are 4.510 and 4.931 KeV and L energies are 0.5 KeV.

The typical K-alpha yield for conventional fusion reaction

d + d --> t + p fusion in Pd

(when it occurs) has been estimated as one per 4-6 x 10^4 conventional d-d fusions, resulting almost entirely from relatively unslowed protons (1.75-3 MeV) [4-6].

A second potential source of X-rays in cold fusion experiments is the decay of tritium. Although its half-life is long, this isotope does decay by emitting a beta particle (electron) with sufficient energy to excite characteristic X-rays in other elements.

It should be noted that some theories predict low-kinetic-energy products. If this occurs, it would not only prevent charged particle detection, but also suppress charged-particle-induced nuclear reactions (such as d-t fusion) and excitation of characteristic X and gamma radiation from the metal.

ABSORPTION

Charged particle measurement is not possible in most cold fusion experiments because of the particles' extremely short range in solids or liquids (typically only some microns to tens of microns) before stopping as a result of repeated collisions. In particular, the ranges of 3-MeV protons, 1-MeV tritons and 0.8-MeV ^{3}He nuclei in $PdD_{0.8}$ are 33 microns, 4.6 microns and 1.3 microns, respectively (nearly the same as the ranges in pure Pd). Ranges in TiD_2 for the same nuclei are 65, 6.5 and 2.2 microns [7].

Ranges decrease for increasing particle charge and sample density, and decrease with decreasing particle energy.

Particle ranges in gases are much longer than in solids, such that even some millimeters of air or D_2 gas between sample and detector should have a comparatively small effect. Vacuum, of course, would have no effect except for the fact that the number of particles per unit area decreases as a function of the square of the distance between the sample and detector in exactly the same way as for any other type of radiation.

Particles emitted at depth in the sample will lose some of their energy in the sample before entering the detector. This fact can be taken into account statistically, but will depend on the angle at which the particle is emitted as well as its depth. It is for these reasons that considerably less than half of charged particles can typically be detected in experiments.

In contrast, gamma or X-rays do not have specific ranges in matter, and do not decrease in energy during their passage. Instead, the intensity of such radiation will decrease exponentially with distance. Gamma radiation of MeV energies is quite penetrating, such that much of it would be expected to escape from ordinary cells. Considerable thicknesses of lead are typically used for gamma shielding.

X-rays, on the other hand, are relatively strongly absorbed by high-atomic-number elements such as Ti or Pd, so that like charged particles their detection would only be possible in particular experimental geometries. For example, the intensity of characteristic X-rays is halved in a few tens of microns in Pd and Ti [e.g 6,8]. The penetrating power of low-energy secondary gamma rays resulting from excitation of other atoms is, of course, intermediate between MeV gammas and X-rays; the half thickness of characteristic Pd gammas is 4 mm in Pd and several cm in water [e.g 3].

CHARGED PARTICLE DETECTORS

One of the two most common types of particle detectors is the silicon surface barrier detector (SSB, also referred to as a semiconductor detector). This detector is typically one to a few square centimeters in area and has a "depletion depth" or active thickness of 60-300 microns. The energy deposited by each charged particle entering this volume can be measured, and will correspond to the total particle energy if the detector is thick enough. Specifically, a 300-micron SSB would completely stop even protons of up to 6 MeV and alpha particles of up to 24 MeV [9]. If an SSB is thin enough that a particle can completely penetrate it, it will still be registered but its energy will be underestimated.

Particle identification "telescopes" can also be constructed by placing a very thin SSB on top of a thick one. A comparison of a particle's energy loss in the first with the total energy ("delta-E versus E") can allow protons to be distinguished from much less penetrating alpha particles, etc. [e.g 10]. Given a sufficient production rate, crude identification with a single SSB can also be accomplished by either covering part of the detector with a very thin foil [11] or decreasing the detector voltage [12], and determining the extent to which apparent particle energies are decreased.

The second common type of particle detector is the track detector; this includes the common CR-39 plastic detector. These are damaged by energetic charged particles in such a way that the damage tracks will erode more rapidly when the film is chemically etched after the experiment. The number of resulting pits gives the total number of charged particles, and the depth and the angle of the pit sides can be used to infer the particle energy and charge [e.g. 7]. For very low count rate experiments, films may be pre-etched in order to locate pre-existing tracks, thus cutting the background for the experiment.

Each type of detector has several potential advantages. SSB detectors are able to monitor events as they occur, which track detectors cannot. Only track detectors, on the other hand, are able to provide information on the track geometries, for instance to show not only that the particles came from the sample but whether they were concentrated in particular areas. Track detectors may also require less modification of an experiment in order to be used even in an electrolytic cell. SSB detectors may also be degraded by hydrogen unless "ruggedized" [9]. Finally, while SSBs can be used for particles with energies considerably lower than 1/2 MeV, electronic noise contributes to background count rates which increase exponentially at low energies [e.g. 7, 13], such that lower energy thresholds between 1/2 and 1 MeV are typically necessary.

Both detector types are relatively insensitive to other forms of radiation such as neutrons and gamma rays, especially in energy ranges above 1 MeV. Thus, the resulting background count rates can be several orders of magnitude lower than for neutrons or gamma rays at surface sites, often in the range of a few total counts per day, and even less for protons. The primary background sources are the decay of radioactive isotopes such as radon (often the major source of alpha particles) and cosmic rays (which especially produce lighter particles).

Cosmic rays can be shielded against to some extent, but alpha emitters may be present even within the detector and sample. In fact, at extremely low counting rates allowance may need to be made for the increased counts from this source when the sample is introduced [e.g. 7].

Nevertheless, the alpha background can in some cases still be decreased dramatically by minimizing the detector's exposure to the air [7], or by interposing a covering thick enough to block alpha particles yet thin enough not to completely stop all protons [14]. An additional factor which may need to be considered at low count rates is the typical variation (as much as several-fold) in the cosmic ray background, both short and long term.

CHARGED PARTICLE DETECTION - EXPERIMENTS

While charged particle production can be inferred from any secondary reactions which they trigger, a method involving direct counting of the charged particles would nevertheless potentially be several orders of magnitude more sensitive, especially since the detection efficiencies of both main types of detectors is near 100% for particles with energies in the MeV range. Thus, for example, detection of 1-MeV tritons as they are emitted could in principle be 10^8 times more sensitive than measurement of the subsequent slow decay of the tritium.

In addition, information on the particles themselves can be quite valuable. For example, measurement of approximately equal numbers of protons and tritons of appropriate energies would be a clear signature of d-d fusion, and the pattern of energy loss in the sample could establish whether they had been produced primarily at the metal surface or at varying depths. However, many cold fusion experiments have clearly demonstrated that many cells produce much more heat than can be explained by the production of tritons. Unexpected energies or identities, on the other hand, could provide valuable information on a nonstandard mechanism. For example, in plasma physics the d + d --> ^{4}He is seen about 1 in a million events. However, in cold fusion cells it may be the predominant nuclear reaction (see article beginning on page 1).

As previously discussed, severe limitations are imposed by the short particle ranges. Nevertheless, the geometry in a variety of experiments has been arranged in order to make particle detection attempts possible. For example, since ion bombardment or cluster impact experiments typically require a vacuum, charged particle detection attempts have been made [e.g. 9,15], and some clear signatures of d-d fusion under such "warm" conditions has been observed [e.g. 12,16]. Charged particle detection has also been attempted in gas loading experiments on thin foils [e.g. 10], with some success reported [e.g. 11, 13], and a few experiments have been conducted to test for charged particle emission during fracture of deuterated solids [e.g.17,18].

A surprising number of electrolysis experiments have been modified, usually to use foil cathodes which form the side or bottom of the cell [e.g. 7, 14, 19-22]; this design is similar to that of permeation cells which have been used to study hydrogen diffusion in metals, except that several microns of gold or some other hydrogen-impeding film is often used to coat the outside of the cathode to prevent deuterium loss. Charged particles have in fact been reported in at least one such experiment, by Taniguchi [23].

Despite the high efficiency and low background, one factor which will always limit detection of cold fusion in such experiments is the unusually small sample volume; fusion at depths of more than 30 microns in Pd would not be observable, so foils used are typically only 10-30 microns thick. Thus highly localized/infrequent events would be less readily detectable. In addition, use of such foils could in principle also alter some metallurgical factors involved in making cold fusion possible. (Incidentally, thin foils also pose practical problems, in that they can be more easily damaged or deformed by loading with deuterium, especially due to the vigorous gas evolution expected at high current densities.)

GAMMA RAY DETECTION

Gamma radiation measurements also have the potential to monitor the fusion rate as a function of time. In addition, if any of the reactions involve the production of gamma radiation, its characteristic energy would indicate the reaction involved.

A variety of types of gamma detectors have been used in cold fusion experiments. NaI(Tl) scintillators such as those originally used by Pons and Fleischmann are fairly common [e.g. 2]. These have moderate efficiencies (tens of percent), but an energy resolution of only several percent. High purity germanium (HPGe or "intrinsic" Ge) detectors also have reasonably good efficiencies, but have resolutions between 1 and 2 orders of magnitude better [e.g. 24, 25].

Gamma ray background count rates are frequently significant, especially at lower energies and at energies characteristic of decays of common radioactive isotopes such as Rn and ^{40}K. Unfortunately, the 2.22 MeV line from the n+p reaction is too close to one such major peak at 2.204 MeV, from the radon decay product ^{214}Bi, to be distinguished from it by low-resolution detectors. Background is generally decreased by (low-activity) lead shielding and by the use of underground sites to greatly reduce the cosmic ray background.

A few groups which have attempted to detect either primary or secondary gamma radiation have been successful [e.g. 26-28], but others have had negative results even though they have detected heat and/or other nuclear products [e.g. 29].

In addition, a few groups which have achieved very high neutron count rates [8, 30, 31] have used these to perform neutron activation (NAA) of elements with high neutron cross-sections, such as silver and indium, in order that the resulting gamma radiation could confirm measured neutron emission rates. (See also a discussion in [32].)

X-RAY DETECTION

X-ray backgrounds are normally very low, often a few counts per hour in appropriate energy windows. However, it should be noted that this background may contain small peaks at the energies of interest, since characteristic X-rays can also be excited by other types of background radiation [e.g. 5].

A variety of methods can be used to detect X-rays. For example, the BARC facility in India has used autoradiography and Si(Li), NaI and HPGe detectors to measure characteristic X-rays excited in samples by tritium decay, and thus confirm the exceptionally high tritium levels [31].

A few experiments have also tried to look for secondary X-rays from the primary fusion reaction, often using similarly modified geometries to those used in charged particle experiments [4, 5, 33, 34]. Briand [34] has noted that both X-ray production and X-ray absorption depend strongly on the atomic number of the element in question, such that emission by Ti during conventional d-d fusion should be 20 times likelier than by Pd, while absorption should be 40 times less, making Ti in principle much better suited for such experiments.

The most interesting positive results have been those of Szpak (since partially replicated by NCFI), which placed X-ray film approximately a millimeter away from the cathode in an unusual electrodeposition experiment [35].

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F. LETTERS FROM READERS

COMMENTS ON CONDENSED ELECTRONS

From Dr. Samuel P. Faile, Cincinnati.

Bostick [1,2] develops the concept of an electron as a closed string with loop radius R and string radius r_O, where r_O is small compared to R. Could such a particle condense into a helix structure akin to the often observed plasmoid found in plasma physics?

A conjecture is developed using some of the data of Puthoff and Shoulders [3]. It is assumed that the electron loops connect during condensation to form an extended figure-eight structure akin to a long polymer. The ingredients for this structure, the electron loops, were considered by Compton to be about 3.9×10^{-10} cm across. It is assumed that about 10^{10} of these electrons combine into the polymer pattern in the form of a helix structure about as wide as the impact crater on the witness plate observed by Puthoff and Shoulders [3]. [They created beads of compact electrons, impacted these beads onto a target disk, and measured the size of the craters formed.]
Puthoff and Shoulders found that condensed electron beads consisting of 10^9 to 10^{11} electrons formed craters about a micron across. [Faile's computations omitted] Thus the helix containing about 10^{10} electrons could form and join into a torus about 1 micron across with each of the million turns in the helix containing about 10,000 electrons in a nearly circular pattern about 10^{-2} microns across.

This electron "polymer" in the form of a toroidal helix would be stabilized by magnetic fields characteristic of a plasmoid. These magnetic fields could be very intense since by joining the electron loops into strands resembling a continuous figure eights pattern the electron charges will be able to circulate around the turns at near the speed of

light instead of just around the individual superstrings of the original electron loops. Instead of individual electrons circulating around a plasmoid, the charges from the electrons can circulate much faster over the surface of a joined superstring pattern in a form of a toroidal helix. The resulting magnetic field would be so intense that the condensed electrons could act as a single particle. If more than one helix is formed the resulting toroidal forms could interlock like a necklace or chain pattern. A long enough necklace could from a ring pattern.

Some structure like the above with electrons moving at about 1/10th the speed of light can remove material, 25 microns diameter, through an indeterminate number of thin ceramic plates or through more than 800 microns of closely spaced 1-2 micron thick plates. [As measured by Puthoff and Shoulders.]

This energetic 'drilling' process may make sense if the condensed electrons catalyzing exothermic surface nuclear reactions. As a layer of atoms on the surface of each plated is fused, the amount of material in each plate behind the fused layer is limited enough so that the material heated by the nuclear reaction will be able to vaporize to the extent that the material will expand and blow out behind the electron polymer helix structure -- thus acting as a propellant. Thus the speed of the electron polymers would be maintained by a jet action making possible further nuclear-reaction-causing impacts onto new surfaces. ...

The nuclear reactions could be caused by the screening effects of many charges or by extremely intense magnetic fields. A thousand electrons could be located within a 0.39 Angstrom thick volume of material.

Cold fusion has been found more likely to occur in deuterated palladium rods that show signs of significant swelling. Perhaps this swelling is accompanied by the formation of many channels with the width of a micron. A network of these channels in a wormhole structure could be conducive to the movement and nuclear effects of the moving electron polymers. [Or of electron beads.] The widening of the channels could produce stresses and microcracking which could generate more electron polymers from arcing processes.

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See also: Samuel P. Faile, "Zero-Point Energy and Possible Application to Cold Fusion, *Fusion Facts*, Vol 2, No 7, pp 17-19, February 1991.

[Dr. Faile's letter is admittedly speculative. However, in view of the recent findings of Puthoff and Shoulders, we find Faile's letter an ingenious adaptation of new knowledge about the possible structure of electron beads and their possible interactions in a cold fusion environment. Ed.]

AN OPEN LETTER TO READERS

Fusion Facts' goal is to provide our readers with as much key information as possible regarding ongoing cold fusion research, in as timely a fashion as possible, together with relevant discussions and background material. Consequently, we welcome any assistance from our readers, including additions and corrections to material in past issues, news or short articles which would be of value to readers of upcoming issues, and preprints of articles which are still in press or reprints of difficult-to-obtain articles (especially in foreign journals and privately published reports).

We also welcome feedback on what else you would like to see in *Fusion Facts*, and what we need to do better.

G. COMO, ITALY CONFERENCE & CALL FOR PAPERS

II ANNUAL CONF. ON COLD FUSION
(ACCF2)

June 29 through July 4, 1991
Villa Olmo, Como, Italy

From BULLETIN No. 1

I. PURPOSE

After two years, the puzzle of **NUCLEAR PHENOMENA IN METAL LATTICES (COLD FUSION) is still with us.** The aim of the conference is to promote the broadest discussion and confrontation on all scientific aspects of this phenomenon. Participation is open to all interested scientists.

II. SCIENTIFIC ORGANIZATION

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