FUSION facts

A Monthly Newsletter Providing Factual Reports On Cold Fusion Developments

ISSN 1051-8738 • University of Utah Research Park •

ISSN 1051-8738 

***Fusion Facts*** **Now Reports on Both Cold Fusion and Other Enhanced Energy Devices.**

**VOLUME 5 NUMBER 7 FUSION FACTS JANUARY 1994**

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**NOTICE**

All papers designated as being "presented at ICCF4" are from the pre-printed abstracts of papers from the 4th INTERNATIONAL COLD FUSION CONFERENCE held over December 6-9, in Maui, Hawaii. These papers will be more carefully reviewed and properly referenced when the full Proceedings are published or when we receive the full paper. Occasional **bold print** is *Fusion Facts'* emphasis. All references to Figures refer to those in the ICCF4 book of abstracts, which we did not have room to publish. *Fusion Facts* will publish the remainder of the abstracts in the February issue.

**Information to be released on February 1, 1994**

A new and exciting theoretical development will be revealed at a press conference on Feb. 1. The February '94 issue of *New Energy News* will feature this important theoretical breakthrough, and *Fusion Facts* will report on it, also.

## A. ICCF4 FINAL REMARKS

**Daniele Gozzi (Dipart. di Chimica, Università "La Sapienza", Rome, Italy).**

A. Role of electric field in Pd

At this meeting, for the first time, the fundamental questions have been addressed: "Why can a D/Pd ratio higher than 0.67 be reached in an electrochemical system when at the Pd/electrolyte interface the $D_2$ pressure is ≈1 Atm?"; What is the driving force which allows this? Have these forces been considered?

It seems to me that notwithstanding several Conferences and hundreds of publications, this topic was never treated, just as if it were well understood and experimentally explained. Two contributions given at this meeting (Gozzi et al., and Fleischmann et al.) try, finally, to clarify this basic concept. I would like to point out that if cold fusion is actually triggered by the D/Pd ratio, most of the experimental work would be performed just to understand and then to control the D confinement.

B. Low energy nuclear reactions

At this meeting some indications, mostly not yet experimentally proved, concerned the so called *low energy nuclear reactions* producing stable isotopes. I believe the diffusion of such information can be a source of further risks to the credibility of our scientific community if these claims are not adequately and quickly supported by independent experimentation.

C. Theory

Theoretical Physics is not my field but it seems to me that no particular novel or significant improvement has been given here. My opinion is that the Preparata theory still represents the theoretical approach closest to the reality of the experimental findings. By making use of only the known concepts of Physics, Preparata applies them to the condensed matter. His open-minded attitude seems not yet familiar to the world of High Energy Physics.

D. General remarks

My expectation in coming here was to hear more experimental results, especially about $^4$He and excess heat, more results of excess heat correlated to Pd metallurgy as well as the loading ratio, and so on. My conclusion is that we have dedicated more time to talk about what we expected than to discuss what we actually found. I believe that it would have been more useful for our scientific community to discuss extensively some relevant experimental results presented here. This would avoid, at this time, a strange feeling of diffuse uncertainty.

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**Boris Guzhovskii (ENECO, Salt Lake City, UT).**

1. The mechanism of cold fusion has not yet been discovered. For identification of nuclear reaction type it is necessary to measure space-energy distributions of all its products and determine the atomic masses and charges. Unfortunately, complete nuclear experiments are absent in the ICCF-4 reports. These experiments are very complicated. For fast charged particles detection it is necessary to use thin layers as targets. These cases are seldom realized in the field of cold fusion. Experimenters must create special conditions for observation of its energy spectra.

2. Nuclear reactions in lattices are distinct from reactions in vacuum conditions. Instead of two-body interaction, here we may have few body reactions (for example, 3D=Li-6 = H-3+He-3) These circumstances will complicate experiment analysis.

3. It is very important to discover the time and quantity correlations between heat and nuclear products in the same experiment.

I hope to see new successful experiment results at ICCF-5.

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**Yan Kucherov (SIA, Lutch, Moscow and ENECO, Salt Lake City, Utah).**

Four years have passed after Pons and Fleischmann's announcement of their discovery. The puzzle still remains. We do not know the origin of the effect, whether it is nuclear or not. Measured nuclear products which can be seen in some experiments are, by many orders of magnitude, inconsistent with excessive heat results. We don't even know whether we are dealing with one or several effects.

On the other hand, the perspectives of developing a new energy source are too great to neglect this field. Though we did not see dramatic break-throughs at this conference, the field itself matured and turned into normal research. And as in any normal research one invests resources and brain power to finally achieve the results.

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**Keiji Kunimatsu (IMRA JAPAN, Sapporo, Japan):**

I have paid great attention to the significance of achieving high deuterium loading in the palladium cathode in the excess heat generation, and have tried to find electrolysis conditions and cathode materials for achieving D/M=1.0, where M is the total number of metal atoms in the cathode. At this conference we had three reports in which D/M=1 was achieved either by choosing appropriate electrolysis conditions or by using new cathode materials. They are:

1. D/Pd=1 on Pd with a deposited thin Pd layer in 0.5 M $D_2SO_4$ by repeating partial discharging/charging cycles reported by F.G. Will, K. Cedzynska and D.C. Linton.

2. D/Pd=1 by applying a high power cathodic current pulses of micro seconds duration reported by F. Celani et al.

3. D/M=1 on Pd-Rh alloy cathodes reported by IMRA JAPAN.

These studies have shown the significance of high deuterium loading in the cathodes in observing Tritium generation in Pd cathode (1), excess heat generation (2) and excess heat generation as a function of D/M (3). However, they have shown at the same time that the higher D/M does not always give rise to the higher Tritium or excess heat generation.

To summarize these data, we now have several options to achieve D/M=1, which has been thought to be essential in observing excess heat generation in electrolysis of heavy water using Pd cathode. But we now know that the high loading is a necessary but not a sufficient condition, as has been pointed out by the group at SRI.

It seems to me that we have passed through a mountain of loading and now should focus our efforts to understanding the sufficient conditions to generate excess heat. To me ICCF-4 was successful in making us aware of this point much more clearly than at ICCF-3.

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**XingZhong Li (Dept. Physics, Tsinghua Univ., Beijing, China)**:

Thanks, Tom, for giving me such an opportunity. I'll try to be quick, so I will use a transparency.

WHAT IS NEW?

1) Excess Heat: Heat after Death (Fleischmann & Pons) or Heat after Life (McKubre).

2) Nuclear product: Helium-4: Gozzi comes with Neon-20, the ratio of $^{20}Ne/^{4}He$. Miles has a better statistics 16/27; more runs have excess heat and still have the correct correlation with $^{4}He$. Yamaguchi repeated his $^{4}He$ measurement again, and now he has a better chance at France. Tritium: Will disappeared at Nagoya; now he comes back with the tritium and the detail of multiple-step loading method for deuterium into palladium. Last year Professor Ikegami said we were crossing the ridge from confirmation to analyzing the mechanism. Now we are at the other side of the ridge. Then, what is the mechanism?

3) Theory: More people are talking about the penetration of the Coulomb barrier. If it is true, then, the enhanced fission should be possible as well.

RECOMMENDATIONS
I am happy, because I feel that I have made the right recommendation to my authorities:

1) Reinforce the "Excess Heat" experiment -- Professor Zhang is from the Institute of Chemistry, Chinese Academy of Science. The electrolysis of pressurized heavy water is now under way at Tsinghua University.

2) Reorient the "Electrical Discharge" experiment -- Professor Wang shows that the anomaly we reported at Nagoya about the high energy neutron ($E_n$ >3MeV) is due to the overlap of the intensive X-ray signals. Professor He found that this low energy part of nuclear radiation might be abnormal. He found an unexpected peak in the Gamma-ray spectrum (~130keV), and Professor Peter Hagelstein is happy about it, because he is looking for a peak near 129keV.

3) Perform new experiments to detect the enhanced spontaneous fission, and to diagnose the high electron density region on the surface layer of palladium using positron annihilation technique.

FUTURE
Show a scale of budget level: Billions of Chinese dollars go into the industry research such as the Volkswagen localization, giant steel mill, etc.; hundred of millions go into the High-Tech program which has seven fields including the energy field; about a million each year for an item in fundamental research in the so called "Climbing Up" project. Currently, cold fusion is considered as one of the possible candidates of the "Climbing Up" project. The funding level is very low, **but it is not considered as a pathological science.** We are working very hard to try to enter the "Climbing Up" project next year. If a 10 kW demonstration unit appears in the ICCF-5, then we may jump into the "High-Tech" program, and you are welcome to Beijing for ICCF-6 in 1996. Thank you.

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**R.A. Oriani (CEMS, Inst. of Technol., Univ. of Minnesota)**:

Speakers before me have already mentioned some of the presentations at this conference which have impressed me, such as Kucherov's glow discharge work, and Gozzi's finding of the production of $^{4}He$ along with excess power. Another of my favorites is the Stringham-George work on sonication of palladium in heavy water, which produced excess power and $^{4}He$. Mizuno's experiments with solid protonic conductors are very impressive; if his claim of $10^4$ times more output power than input power is verified, his technique is likely to supersede all other approaches. Finally, I would like to remark on the admirable openness of most of the participants at this conference. Frank discussions and useful suggestions were the norm. This behavior is commendable and also necessary in view of the fact that most of us in cold fusion research are funded very poorly or not at all. Sharing information, pooling the bits of knowledge that we develop individually, is extremely important for making progress in the elusive field of cold fusion.

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**Debra Rolison (Surface Chem. Branch, Naval Research Lab, Washington D.C.)**:

I realize that part of a panel's purpose is to describe their view of the elephant. Here is mine.

Two years ago in Como {*at ICCF2*}, Mike McKubre laid down a challenge to the entire community when he recommended that work should not be published or publically presented without a determination, preferably *in situ*, of the loading ratio {*D:PD*}. I think this meeting has made it clear why that was an important challenge to the community, because since 1991 when McKubre made work for you {*the researchers studying the Pd-deuterium system*}, a number of protocols have been established to achieve loading ratios above 0.85 {*at near ambient temperatures*}, so one can now achieve *sufficiently high* loading ratios where one has a chance to observe anomalous effects. I would like to modify this challenge for the future by giving you some extra work regarding materials science that will, I hope, lead to more control {*of the results*}. Future papers that are published in this area should include analysis and characterization of the metallurgy of the bulk material before and after loading the material to high levels with a hydrogen isotope. There should be information on the identity and concentration of the chemical impurities in the metal; there should be information on the grain sizes and grain orientations comprising a polycrystalline sample, and there should be information on the defect and dislocation densities in the metal -- this information should be available to the entire community any time a piece of work is presented or published.

I am convinced that the consequence of meeting this challenge in materials science will be the establishment of even greater protocols to achieve, reliably, anomalous effects. Researchers now have sufficient information to allow the preparation of palladium deuteride where the loading ratio exceeds the value for the ß phase. I think that is what the highlight has been of this meeting -- that one can finally start to compare different kinds of materials and different metallurgies for a given material.

All of us should recognize that a range in the quality of the experiments {*in the cold fusion area*} exists -- and that breadth has been useful in the past because there is much that can be learned from different approaches. However, although there are some extremely high quality experiments out there, there are many that need to become more so.

As scientists, we have all had our measure of arguments in private with colleagues about the validity of cold fusion research and I would like you to think about a strategy I use. As an American, I pick an effort in this country that I am very familiar with -- one that I have visited and where I have read the papers on the results -- and that is the effort at SRI. And I describe it as one of the most sophisticated, thorough, well thought-out, and artifact-seeking experiment I have ever seen -- **and if our entire scientific community cannot accept the results from that kind of high quality experiment, then we have no business accepting anybody's scientific data in any area. And that {*statement*} always hits people in their gut.**

Now we are all aware that there are many different experiments and procedures in this areas, but all of us know of high quality experiments in this field and the experiments need to be rewarded for the effort that has been put into them.

I look forward to France.

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**Franco Scaramuzzi (ENEA Frascati, Rome, Italy)**:

Three features, in my opinion, most characterize this conference:

1. There is a certain number of new results, among which I like to quote: heat excess in gas loaded systems (Kucherov) and in "protonic" conductors (Mizuno).

2. The evidence for heat excess is by far more striking than that for nuclear emissions, and the correlation among them is still quite obscure. The experiment planned at the Gran Sasso Laboratory (neutron background $10^3$ times less than at the sea level) in a collaboration between my group, ENEA/Frascati, and a group of INFN/Bologna, in which excess heat and nuclear emissions will be measured at the same time, should be able to give an important contribution to this issue.

3. In one field - heat excess in electrolysis with Pd cathode and heavy water - a high level of confidence has been reached, that I will sketch with the following notes:

a. The measurement of heat excess and its correlation with D/Pd ratio has been reproducibly demonstrated in many experiments, among which I like to quote, as impeccable for procedure and experimental skill, those of SRI (McKubre) and of IMRA/Japan (Kunimatsu).

b. Among theories, I want to quote that of Preparata et al., for two reasons. The first is "sentimental": it involves the study of collective phenomena, thus of macroscopic quantum systems, which are familiar to me, since I performed research on superfluid helium for more than 20 years. (In any case, I know that they do exist!) Second, it has been able to make provisions which serve as a useful guide to the experimenter:

- a threshold for D/Pd ratio, which has been proved beyond any doubt;

- the finding of $^4$He as the main nuclear ash of a possible nuclear reaction: the evidence for this ash is increasing (remember the paper by Gozzi and Gigli, of the University of Rome 1, showing not only a confirmation, abut also a correct way to perform this delicate measurement);

- the possibility of the presence of a third phase in the palladium deuteride, which could involve a detectable phase transition: very little has been done on this by now, but it represents a very interesting field of investigation in condensed matter physics.

c. There is a clear feeling that this field is presently investigated with very qualified tools: let me remember the use of the cathode as a membrane, in order to better understand the dynamics of D in Pd (ENEA/Frascati), and the study "in real time" of the deuteride cell parameter, through X-ray spectrography, which permits one to follow the mechanisms of D-loading in Pd during electrolysis (IST/CNR/Frascati in collaboration with ENEA/Frascati).

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**M. Srinivasan (BARC, India, on leave at SRI, Menlo Park, CA)**:

Of the 155 or so papers presented, about 50% (78 papers) understandably dealt with Pd-$D_2O$ electrolysis; an additional 30% were theoretical papers. However it is the balance 20% or roughly 30 papers that caught my attention.

These papers covered a broad spectrum of topics drawn under the umbrella of cold fusion - like the big banyan tree in the beautiful island of Maui, spreading by growing roots from the branches down to the solid ground!

The enclosed table summarizes the distribution of papers amongst the various systems.

The fact that there were at least a dozen proton-based (or hydrogen-based if you wish) experimental papers reporting positive results is significant. This includes 7 light-water electrolysis papers.

The substantial improvement in the sophistication of the experimental techniques used by many experimenters was noteworthy.

I was rather surprised by the wide use and acceptance of the concept of nuclear transmutation reactions being highly relevant to the phenomenon of cold fusion. This I believe is significant. No doubt the glow-discharge experiments of Kucherov et al. is responsible for this.

Finally, the announcement of the launching of a popular technical magazine solely devoted to cold fusion to be published by the publisher of the highly successful BYTE magazine of the computer industry is a historic milestone in the history of cold fusion.

If I were asked to say whether there were any disappointments, I would say the non-confirmation of detection of a nuclear ash signature in the form of $He^4$ in Pd-$D_2O$ electrolysis, in spite of laudable efforts by several groups.

ICCF-4 : DISTRIBUTION OF PAPERS ~ 155

| | LOADING TECHNIQUE | DEUTERIUM BASED | HYDROGEN BASED | OTHER SYSTEMS |
|---|---|---|---|---|
| 1 | Electrolysis (aqueous) | **78** Pd-$D_2O$ | 7 (See list) | |
| 1a | Electrolysis of molten salts | - | 1 (Liaw) | |
| 2 | Gas/plasma discharge | 4 | 1 (Dufour) | |
| 3 | Gaseous Loading | 2 (Claytor, Mizuno) | - | |
| 4 | Ion Beams | 4 | 1 (BARC) | |
| 6 | Ultrasonic waves | 1 (Stringham) | 1 (Blue lasers) | |
| 7 | Exotic Materials (other than Pd, Ti, Ni) superconducting, piezoelectric, etc.) | 4 | - | |
| 8 | Miscellaneous | | | 1 Biological Transmutation<br>1 Electron Bombardment |

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Excess Heat in Ni-$H_2O$ electrolysis (alkali carbonates)

| | |
|---|---|
| 1 - Ohmori/Enyo | Japan |
| 2 - Notoya | Japan |
| 3 - Matsumoto | Japan |
| 4 - Bush/Eagleton | USA |
| 5 - Bazhutov et. al | Russia |
| 6 - Criddle | Canada |
| 7 - Ramamurthy et al. | India |

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**Edmund Storms (ENECO, Salt Lake City, UT)**:

A Very Unscientific and Personal History of the Cold Fusion Effort

I will try to describe the field in five stages. We are now in the transition between Stages 3 and 4.

Stage 1 started when Profs. Pons and Fleischmann partly jumped and were partly pushed into the Colosseum of public awareness with their claim for low energy nuclear fusion. Sadly, the lions were hungry. Fortunately for Prof. Jones, his claim for a similar but smaller effect was not as tasty to the skeptics.

This claim caused every scientist, who was lucky to have an imagination and access to suitable equipment, to attempt a duplication of the results. From the smoke and confusion arose several positive results. These were very carefully examined and were rejected. A few negative results were reported by several well known laboratories. These were given no examination and were accepted. Thus began the double standard that has plagued the field ever since. It is ironic that recent analysis shows that one of these negative studies could not possibly have produced positive results. One other accepted negative study apparently actually produced small positive results. This stage of unrestrained enthusiasm ended with the publication of the ERAB report, a very incomplete and harmful document showing only a minor amount of objectivity.

With the advent of Stage 2, the field went underground and became defensive. Work continued at isolated laboratories by people whose special circumstances made them immune to the growing negative attitude. Much of this work wasted time trying to prove the reality of the effect rather than understanding its nature. Frank Close made the case for the skeptics and the message was carried into the lion's den by Douglas Morrison. Eugene Mallove wrote a clear account of the positive results and several scientific reviews also supported the reality of the effect. Thus, the battle was joined. During this time, the dedicated skeptics did a service to the field. They encouraged better work and forced an appreciation of the issues. Gradually, the work continued with the support of a few courageous institutions, EPRI being a major contributor to the sparse studies in the U.S.

Stage 3 began when Japan and several other countries initiated major research programs, both government and privately sponsored. Significant efforts are under way in India, Italy, Russia, and recently in China. Over 1000 papers are available in the field, many peer reviewed and many showing positive results. This growing work resulted in improved methods and new ways to initiate the effect. At the present time, over 8 different environments have been found to produce the phenomenon, some completely reproducible. This fact alone should cause some pause on the part of skeptics. In addition, evidence for several different types of nuclear reaction is accumulating. Indeed, some of the results are still too amazing for even people in the field to believe.

As new evidence accumulated, the contribution being made by skeptics changed. In general, they have failed to keep up with the field and continue to complain about irrelevant issues. The two recent books by Prof. Huizenga and Gary Taubes failed completely to present a balanced view. In addition, the press has not been much help in presenting the facts. As a result, important issues are not receiving the necessary attention and unnecessary confusion is being spread. The field deserves better treatment. Active skeptics and journalists who distort the facts should consider how they will be viewed should this field eventually be accepted.

On the other hand, by spreading doubt and confusion these skeptics have allowed a few of us to achieve intellectual and financial advantages that would not be possible had major institutions been in the field. As a result, many people will be in a very good position to profit when Stage 4 starts. For this reason, some skeptics should be thanked. Therefore, I would like to suggest an award for those people who most successfully keep the world in the dark. This award would be called the "Flying Pig Award" in memory of past comments about how cold fusion would be proven real when pigs fly. Nominees are being accepted.

Stage 3 is now gradually changing to Stage 4. In Stage 4, the U.S. government and major companies will realize that the phenomenon is real and is extremely important. These new converts will look around for someone who knows how to do competent work and will find very few people available. Those of us in the field can expect to ba awash in money and attention. Only patience is needed at the present time to realize this reward.

Stage 5 will come when a working device is found on shelves at the Japanese equivalent of WalMart. This stage is still in the future.

## B. NEWS FROM THE U.S.

### CALIFORNIA - UNIFYING MODEL

R.T. Bush (Phys. Dept., Calif. St. Polytech. Univ., Pomona, CA and ENECO, Salt Lake City, UT), "A Unifying Model for Cold Fusion," presented at ICCF-4.

AUTHOR'S ABSTRACT

A theoretical model has been devised that accounts for the heavy water excess heat effect (Fleischmann and Pons) and light water excess heat effect (Mills and Kneizys, Bush) as resulting from genuine cold fusion. Among the features of interest are the following: The model (1) Provides a unique and highly novel mechanism to sufficiently enhance tunneling through the Coulomb barrier to account for empirically-observed fusion rates, (2) Accounts for the role of lithium in electrolytic experiments, (3) Accounts for the depletion of $Li^6$ relative to $Li^7$ observed by Thompson in used palladium cathodes and shows that it is associated with a difference in reduced masses rather than quantum symmetry, (4) Predicts excess power density ($W/cm^3$) as a function of loading, S, to be as follows for the D-D case for the heavy water-Pd system: $P(S) = 26.07 \cdot S \cdot 10^{[23.6 - (24.774) \cdot S \uparrow -1/12]}$ $(W/cm^3)$. This is a strictly theoretical formula and does not involve a fit to power density data, (5) Accounts for McKubre's threshold loading criterion of about S=0.9 (in order to begin observing excess power) on the basis of this loading-power density formula, (6) Accounts for the lower level Fleischmann-Pons excess power regime (about $6W/cm^3$) as connected with the tetrahedral configuration loading ($S \simeq 1.25$), (7) Predicts a loading of about $S \simeq 4.04$ for the excess power density (approx. 4 $kW/cm^3$) achieved by Fleischmann and Pons in their "boil-off experiments" and by Bush and Eagleton in their thin film experiments (cathode: 5 micron thin film of Pd on a silver substrate), (8) Can account for tritium and neutrons; in particular, it can account for the result of Bockris's curve for which tritium production mirrors excess heat production, but only at about one-thousandth of the level to account for the latter, (9) Can account for the examples of cold fusion suggested by the CAF Hypothesis ("Cold Alkali Fusion") such as D-D, Li-D, Li-p, Na-p, K-p, Rb-p, and Cs-p, which supports findings of $He^4$ for the heavy water case, and calcium and ($Sr^{86}/Sr^{88}$), respectively, for the K-p case and Rb-p case, (10) Suggests a relatively "radiationless" de-excitation mechanism. (11) Can

apparently account for "filament fusion" a longer standing nuclear mystery than cold fusion.

## CALIFORNIA - CHEAP ELECTRIC POWER?

Dr. Robert Cornog (Consultant), "Cheap Electric Power From Nuclear Fusion?" presented at ICCF4.

AUTHOR'S ABSTRACT

The projected costs of producing electric power in a thermal power plant using cold fusion as the source of energy are here evaluated and compared with the costs of other power sources. To this end, the costs of producing electric power are divided into several components. One component is the cost of the fuel consumed, be it fossil or nuclear in origin. A second component is the fixed costs. Here the fixed costs include such items as interest on borrowed capital, depreciation, maintenance and repair, labor, taxes, insurance, profit, etc. A third component, of increasing weight for both chemical and nuclear fueled plants, is the added costs caused by the environmental impacts attendant to their operation and--for nuclear plants--the added safety measures needed to reduce the probability of nuclear accident.

For more than 20 years, the cost of fuel used in contemporary fission-fueled nuclear plants has been about one-third the cost of the fuel used in chemically-fueled power plants. Reasons will be given for believing that this same favorable balance will continue to exist in favor of fusion-fueled plants. In concept then, one can take these possible savings in fuel costs and apply them to offset the possible increased fixed costs of fusion-fueled plants. This trade-off is discussed and numerically evaluated in the full text of the paper.

Studies cited by Logan and others suggest that, as now conceived, thermonuclear fusion power plants may have fixed costs as high as $25,000 per kilowatt. Other numerical examples will be cited. In addition, some thoughts relevant to the probable costs of cold fusion plants will be discussed.

Another factor is especially important in both thermonuclear and cold fusion types of fusion powered plants. In the case of most cold fusion cells, part of the output heat energy must be converted to electricity and is then used to power the electrolytic action in the fusion cell. A similar situation will exist in thermonuclear power plants. Part of the output electric power is to be diverted and used to heat the plasma up to ignition temperatures. It is shown that in both cases, unless the heat output of the fusion device is at least 10 or more times the required electric power input, the resultant overall efficiency will suffer; the cost of the residual useful portion of the electric power output would be too high to be competitive.

One more component of cost requires special attention: cost penalties resulting from adverse environmental impact factors. For example, increasingly expensive measures are being required to cope with the sulphur dioxide and nitrous oxides found in the exhaust stack gases from fossil fuel plants. Another example is the noxious radioactivity that is normally produced during the operation of both fission and thermonuclear fusion power plants. Expensive shielding, safety features, and decommissioning expenses are usually required. It is on this issue that cold fusion power plants may have a tremendous advantage over both fission and thermonuclear plants. In contrast with thermonuclear fusion, some forms of cold fusion have been reported that are unaccompanied by the production of neutrons and induced radioactivity. The implications of this difference will be discussed and evaluated.

## CALIFORNIA - POLYNEUTRONS IN C.F.

John C. Fisher (Carpinteria, CA), "The Role of Polyneutrons in Cold Fusion Reactions," presented at ICCF4.

AUTHOR'S ABSTRACT

Energy release during cold fusion experiments far exceeds that which could be produced by chemical reactions. Nuclear reactions must be responsible. Deuterium fusion was initially thought to have been the energy source but this reaction has been ruled out by the extremely low levels of neutrons and of tritium that are observed.

Cold nuclear reactions cannot be mediated by charged particles because of the Coulomb repulsive force. Neutral mediating particles are required. We are familiar with the family of reactions mediated by neutrons, where uranium or thorium nuclei accept neutrons, undergo fission, and release additional neutrons that can sustain a chain reaction. But because of their scarcity neutrons must be ruled out as the principal mediating particles for energy generation in cold fusion reactions.

It is suggested that polyneutrons with mass numbers $A \geq 6$ are bound and are stable against strong and electromagnetic decay, and that polyneutrons are the principle neutral particles mediating cold fusion reactions. It is further suggested that polyneutrons can grow to extreme sizes in successive interactions with ordinary nuclides from which neutrons are stripped and fused with the growing polyneutrons. Because of the long lifetimes of polyneutrons, on the order of $10^3 A^{-1}$ seconds before one of their constituent neutrons decays to a proton and the resulting charged nuclide can no longer participate in cold reactions, polyneutrons can grow from an initial 6 neutrons to a final $10^9$ neutrons before the fusion process terminates.

Even though as much as $10^{16}$ eV energy may be generated per polyneutron, many polyneutrons are required to generate the energy observed. It is suggested that they are produced in a chain reaction based on the polyneutron-generating reaction $^1n + {^6H} \rightarrow {^6n} + {^1H}$ (where $^6H$ is suggested as a previously unrecognized stable isotope of hydrogen with isotopic spin 3) and the neutron-producing reactions $^6n + {^APd} \rightarrow {^{A-2}Pd} + 4n$. Together these reactions can sustain a chain reaction and can provide a supply of polyneutrons for fusion growth. The neutron level associated with the growth of polyneutrons generated in this chain reaction is many orders of magnitude smaller per unit of fusion energy than that associated with the deuterium fusion reaction.

Topics to be discussed include the stability of $^6H$, the nature of the chain reaction, the growth of polyneutrons in the reactions $^An + ^7Li \rightarrow ^{A+2}n + ^4He + ^1H$, where substantial energy is released with $^4He$ and $^1H$ reaction products, and the growth of polyneutrons in the reactions $^An + ^BPd \rightarrow ^{A+2}n + ^{B-2}Pd$ (for A>20) where the reaction products are transmuted palladium isotopes.

### CALIFORNIA - NUCLEAR PROLIFERATION IN C.F.?

Joseph Peter Goukas (J&J Manufacturing, Verdugo City, Calif.), "Cold Fusion and Nuclear Proliferation," presented at ICCF4.

AUTHOR'S ABSTRACT

Cold fusion anomalies are reviewed for their possible impact on nuclear proliferation. Even without a consensus regarding the processes generating the anomalies, some observed properties of "cold fusion" experiments suggest reasons for concern.

Reactions of most concern would generate fissile material from nuclear source material by either: (a) generating free neutrons, or (b) directly transferring neutrons to nuclear source material nuclei. Such reactions will impact nuclear proliferation only if their reaction rates are many orders of magnitude above those reported thus far in cold fusion experiments.

The cold fusion literature is reviewed for indicators of reactions (a) and (b), and indicators of potential for high reaction rates. Of particular interest are high-Z anomalies, chain reactions, low energy anomalies, conditions for changing branching ratios, isotopic changes, bursts, and neutron activation.

Also examined are other hazards from tritium generation, radionuclide generation, non-nuclear intense energy sources, and unusually high neutron moderator cross section, all reported in cold fusion experiments.

### CALIFORNIA - FL-P EFFECT IN 1994

Michael E. Melich (Phys. Dept., Naval Postgrad. Sch., Monterey, California), and Wilford N. Hansen (Phys.Dept., Utah St. Univ., Logan, Utah), "Back to the Future, the Fleischmann-Pons Effect in 1994," presented at ICCF4.

AUTHORS' ABSTRACT

It has been about 148,522,000 seconds since Fleischmann and Pons publicly reported the discovery of the FP Effect. In Harwell reporting style it has been about 2,475,000 minutes and in SRI/EPRI's it has been about 41,256 hours. During that time SRI/EPRI could have run about 26 to 40 experiments per apparatus and they have reported conducting over 75 experiments before their accident in January 1992. Harwell could have run about 40 with each of their FPH calorimeters, a total 16x40 = 640, and 51 experiments with their single Isothermal calorimeter - yet, their effort collapsed after an intense 70,000 minutes of experimentation, about 20 experiments. Why did some groups press on while the others did not?

We have examined and analyzed some of the experimental records of the Harwell group, reviewed and analyzed some of the data from Fleischmann and Pons work of 1990, and reviewed the published work of SRI/EPRI. We have also been privileged to visit working laboratories and discuss experimental efforts and examine data of defunct efforts. One theme comes through, the *a priori* expectations of a research team and its leaders set the standard for defining successful or failed experiments. From their first announcement the signature of the FP Effect was, and remains, excess heat. Yet the preoccupation of the bulk of the scientific community has been with the search for "nuclear ash". Failure to find the "expected" nuclear ash of fusion reactions blinded and deafened the scientific community. In retrospect a brief announcement that the PdD electrolytic system produces excess heat without offering a production mechanism would have forced a non-nuclear experimental focus, which only now is being followed. Some 57 months after the first announcement by Fleischmann and Pons the scientific community is regaining its sight and hearing and will soon achieve a state of curiosity about what was and remains a great mystery - Why does the PdD system produce excess heat? The question then: Will the attention this time be on scientific experimentation and discourse? In the next chapter of the FP Effect saga rules of common courtesy and civility in both the formal and informal communications channels are vital for the health of the scientific enterprise. The willingness to characterize without having done your research hurts all of science and diminishes scientists in their own eyes and those of the general public.

### CALIFORNIA - OPPOSITION AND SUPPORT

Mario Rabinowitz (EPRI, Palo Alto, California), Y.E. Kim (Dept. Phys., Purdue Univ., Indiana), V.A. Chechin, and V.A. Tsarev (Lebedev Phys. Inst., Rus. Acad. Sci., Moscow, Russia), "Opposition and Support for Cold Fusion," presented at ICCF4.

AUTHORS' ABSTRACT

Modern science has never been so strongly and so long divided, as it has with respect to the phenomena of Cold Fusion (CF). Bifurcation persists because there is still only a sparse experimental meeting ground between the two camps. Conventional theory appears so diametrically opposed to the possibility of CF that little room is left for commonality in the theoretical realm. Experiment should and will be the final arbiter. Nevertheless, a theoretical existence proof, i.e. a proof of principle would go far in putting to rest reservations and doubts regarding the reality of CF.

Our emphasis will be on the theoretical issues in a search to see if a reasonable model of CF exists. For the last two years we have been working on a review of theoretical models for Cold Fusion. We were motivated to understand CF because at least certain of the phenomena appear undeniably real to us. The problem of an adequate theoretical model of CF has turned out to be no simpler than the

problem of its unambiguous experimental proof. Many books and reviews have been written on the subject of CF by both its opponents and proponents. There is a serious need for a balanced account. It is our goal to present a perspective that is as balanced and objective as possible. Where feasible, we will point out shortcomings in the theory and experiments both by advocates and adversaries. We will only briefly cover the phenomenology, as previous CF review papers have extensively covered the experimental results. My paper (in the same spirit as our collaborative effort) will primarily focus on a probing theoretical inquiry that is equitable to both sides of the issue.

Theoretical Opposition and Support for Cold Fusion

It now appears likely that CF is a sporadic, non-equilibrium process. The initial expectation of a considerable number of theoretical publications was that CF is a continuous process associated with steady state conditions in a lattice. In this context, considerations were given to the difference in interatomic fields in a solid than in a plasma due to electron screening. The solid lattice environment permits the mutual approach of free deuterons (d) to much closer distances than they could otherwise be at ambient temperature. Although the average separation of d's is about 1.4Å in heavily loaded Pd, the d's can be in equilibrium at a separation as close as 0.94Å. This is closer than the 1.11Å separation of d's in $D_2^+$ but is not as close as the 0.74Å in $D_2$, which gives no measurable fusion rate. However, closer separation may be possible in non-equilibrium processes.

Calculating tunneling probabilities for the Coulomb barrier between two d's, and their sensitivity to shielding can quickly make us aware of reasons for pessimism followed by optimism with respect to CF. In the context of $\alpha$ emission, in 1928 Gamow first derived the tunneling (transmission) probability $G = e^{-2\gamma}$ through the mutual Coulomb barrier of two particles of charges $Z_1e$ and $Z_2e$, when the center of mass (CM) energy E is much less than the barrier height, in e.s.u.

$$\gamma = \frac{1}{\hbar}\left(\pi Z_1 Z_2 e^2\right)\sqrt{\frac{\mu}{2E}}$$

where $\mu = m_1m_2 / (m_1+m_2)$ is their reduced mass, and $\hbar$ is $(1/2\pi)$ Planck's constant. For two d's taking E ~ (1/40) Ev for illustration, $G \sim 10^{-2730}$, and in free space the classical distance of closest approach would be ~580Å. G is extremely small supporting good reason for pessimism about CF. By introducing a simple shielding model, we shall see that electron screening of the barrier can increase the tunneling probability by more than 2600 orders of magnitude.

This paper will examine both the theoretical opposition and support for CF. Leggett and Baym presented the most general and most pessimistic limitations concerning the reduction of the d-d Coulomb barrier in a solid by electron screening in the equilibrium state. The relevance and limitations of their view will be considered. **Perhaps the most notable theoretical support for CF comes from the Nobel laureate Schwinger who contends that the d's encounter a relatively narrow Coulomb barrier due to zero-point oscillations in a solid.** Lamb is another Nobel laureate who also lends support to the possibility of CF with a heavy effective electron mass model. These and other supporting models will be explored.

Situations analogous to the present situation in CF will be shown to have occurred in other areas such as superconductivity, high-temperature superconductivity, and semi-conductors. Therefore, it is important to approach this subject with an open mind which does not preclude critical appraisal and the eventual acceptance of substantial evidence and worthwhile arguments. Since presently there is no consensus on what constitutes "normal" CF, one can hardly call anything abnormal in this field, because it all goes counter to the common wisdom.

## CALIFORNIA - HEAT PRODUCTION EQUATION

J.L. Waisman (Consultant, Southern California Edison Co., Irvine, California) and N.J. Kertamus (S. Cal. Edison Co., Rosemead, California), "Excess-heat, Heat Production Equation," presented at ICCF4.

AUTHORS' ABSTRACT

This paper presents a non-empirical macro-concept or heat production equation for predicting the excess heat output of deuterated metals via the so-called cold fusion event. The equation can be used as a tool to guide research in short-cutting efforts to reach the commercial phase. Experimental results of cold fusion research available in the published literature are consistent with this macro-concept. The concept or equation implies that other routes of loading a metal lattice with deuterium, and the use of metals other than palladium, should also be effective in achieving excess heat production.

The following relationship is proposed, based on the macroconcept:

$$J/V = K'\{(D/Pd)\ (\exp(-Q/RT))\ (\mu)\}.$$

The terms J/V are the excess heat density, and K' is an experimental constant characteristic of the nuclear event or events. The D/Pd is the deuterium to palladium atom ratio in the lattice, Q is the average diffusion activation energy of deuterium in the palladium. The term R, of course, is the gas constant, T is the absolute temperature. The term exp(-Q/Rt) is proportional to the average jump frequency of the deuterium in the lattice. The term $\mu$ is the chemical potential of the deuterium in the filled lattice.

Temperature being the most important term in the equation, impacts all the other variables including the average jump frequency, chemical potential, and the D/Pd ratio. The phase diagram of the Pd-H system is useful in showing the solubility limits in terms of temperature, pressure or chemical potential, and concentration. Only two of these variables need to be specified. The rate of excess heat predicted by the equation is independent of whether the lattice is filled by electrochemical means or by deuterium gas.

Another subtle point inferred from the production equation applied to electrolytic cells, is the importance of heat transfer from the cathode to the electrolyte and between the electrolyte and the reference bath. Heat transfer from the cathode into the electrolyte directly controls the cathode temperature, and thus, has a major impact on the excess heat performance of the cell. Measurement of cathode temperature is, therefore, a critical issue in conducting excess heat production experiments.

Examples of published experimental results consistent with the heat production equation are presented:

1. Excess heat production is an exponential function of the D/Pd ratio as predicted by the equation.

2. Experimental plots of current density versus relative excess heat for different diameter cathodes is very similar to predicted plots of D/Pd versus the same variables.

3. Experimental plots of cathode diameter versus relative excess heat for varying current densities are similar to those predicted for varying D/Pd ratios.

4. Fleischmann-Pons experimental data are convincing evidence of approximately uniform excess heat production throughout the bulk cathodes.

5. The magnitude and timing of excess heat densities and the temperature changes of the cathode during Fleischmann-Pons forced-boiling tests follow the pattern predicted by the heat production equation.

With reasonable assumptions, the heat production equation provides a plausible explanation for heat bursts and runaway temperature in electrolytic cold fusion cells. Such runaway cells likely reflect heat transfer limitations on the cathode. The heat production equation predicts that pressurized cells or reactors operated at the proper temperature will be a significant source of cold fusion energy.

Moreover, the heat production equation can serve as an important guide to predicting cell or reactor performance without requiring an understanding of details surrounding the nuclear events.

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## COLORADO - HIGH-PRESSURE CELLS

H.E. Ransford, III and S.J. Pike (Nova Res. Group. Inc., Denver), "Apparatus for Safely Extending Cold Fusion Investigations to High Temperature, Pressure, and Input Power Regimes," presented at ICCF4.

AUTHORS' ABSTRACT

The Electrolytic Thermal Cell™, or ETC, reflects the goal of assured safe operation at temperatures to 350°C, pressures to 3500 psi (250 atm), and electrolysis input powers up to 1 kW. The core of an ETC unit is a high pressure electrolysis chamber of thick-walled stainless steel construction with a structurally embedded cast silver thermal dissipator in its lower section. The dissipator is tightly coupled to the calorimeter or boiler section, which has an integral, pressurized coolant (working fluid) reservoir.

The coolant, a fluorinated organic liquid, $CF_3CH_2OH \bullet H_2O$ is thermosiphoned from the reservoir past the thermal dissipator, where it boils. Entrained droplets are then centrifugally separated from the vapor and returned to the reservoir. After a secondary demisting stage, the saturated hot vapor exits the ETC to pass through flow measurement devices and into condensing coils. Recondensed coolant is pumped back into the boiler reservoir at its working pressure, up to 750 psi.

The containment vessels thermally isolate the experiment as well as protect the experimenter and laboratory from overpressure events.

The outer containment vessel, which encloses the entire calorimeter and electrolysis chamber, and the inner containment vessel, which encloses only the upper portion of the electrolysis chamber, are vacuum insulated, double-wall, heavy gauge stainless steel shells, as are the calorimeter/boiler/reservoir walls. The normally evacuated space between the inner components and the outer vessel can also be filled with neutron moderation and absorption materials.

Access to the electrolysis chamber is made through ports at the top of the outer and inner containment vessels. These ports also hold feedthroughs for instrumentation. Electrolysis power is supplied through a fail-safe connector within the bottommost port. Contact in the high current connector (100 Amp continuous, 2000 Amp surge) is mechanically established only when rough vacuum is attained within the ETC evacuation region. If leakage causes this pressure to rise above a threshold level, the safety switch will immediately open.

Heat losses via and within the coaxial power conductor are largely absorbed by the incoming coolant flow, thus kept in the calorimeter.

All active electrochemical components, i.e. electrolyte, cathode, anode, reference electrode and recombiners, are contained in sealed cartridges which can be inserted or removed via the top access ports. The interchangeable cartridges reduce experiment turnaround or cell maintenance time. Cartridges remain sealed during exchange to prevent pre- and post-experiment material contamination or loss. The spacing between the anode and cathode may be adjusted manually or automatically via linkage which passes through the 'tail' of the cartridge.

The ETC is also designed for versatility. For example, following preloading of the cathode through electrolysis, the cell may be evacuated and high voltage, glow discharge operation initiated.

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## HAWAII - ELECTRON-CAPTURE MODEL

George Andermann (Dept. Chem., Univ. of Hawaii), "The Nature & Consequences of the Electron Capture Model for Rationalizing Excess Energy Production in Cold Fusion," presented at ICCF4.

AUTHOR'S ABSTRACT

Previous theoretical rationalizations of the cold fusion phenomenon have been plagued by a number of riddles, the most important of which has been the apparent juxtaposition of the causes of excess energy. During the early days of this era the nuclear physicists claimed that any excess energy had to be caused by conventional chemical processes, while the chemists claimed that excess energy production had to have nuclear mechanisms involved. In more recent times theory has tended to swing towards the postulation of new kinds of dissipation of nuclear energy via various coupling and/or coherent radiation field effects, or even, perhaps, more drastically via the postulation of new kinds of cooperative nuclear phenomena involving solid state mechanisms. In all of these efforts new physical laws had to be postulated.

In what follows below there is no new physics invented. It is postulated that with the assumption of the electron capture (EC) model by a deuteron, which, incidentally, is the only hydrogen isotope that can obey the Einsteinian model of exothermicity, it is possible to account semiquantitatively for all of the hitherto reported production of nuclear events, and what is even more important, it is also possible to account fairly accurately for the production of various levels of excess energy production as well as for the lack of any production of excess energy.

Arguments will be presented that via the EC mechanism, even in terms of the independent particle model, it is possible to account for the production of low levels of excess energy via beta heating, which is a necessary consequence of the nuclear transformation steps due to the EC mechanism. Moreover, it will be shown that one of the consequences of the EC mechanism is the possibility of low energy electron phenomena in the lattice which include conventionally acceptable low energy-many particle phenomena in terms of cooperation and/or correlation, thus enabling the creation of very high levels of excess energy depending upon the rate of production of EC, as well as upon the lifetimes of various excited states. In this connection it should be noted that an attempt will be made to rationalize quantitatively how the EC production rate is dependent on such factors as the deuterium loading of the lattice (and this represents a genuinely significant problem in chemistry), the nature and extent of collisional chaos, and the critical dependence of the valence electron cloud deformation of deuterium due to the unusual lattice dynamics involved in cold fusion.

In summary, an attempt has been made to show that the production of excess energy, while dependent on precursor nuclear phenomena, is primarily dependent on conventional solid sate low energy electron and lattice dynamics, where full account is taken of the low energy interparticle and correlative radiation effects. In short, according to the model proposed the phenomenon of cold fusion may be best termed as being in the new interdisciplinary field of solid state electron-nuclear chemical physics.

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## INDIANA - BARRIER TRANSPARENCY

Yeong E. Kim and Jin-Hee Yoon (Dept. Phys., Purdue Univ., Indiana), Alexander L. Zubarev (Racah Inst. Phys., Hebrew Univ., Jerusalem), and Mario Rabinowitz (EPRI, Palo Alto, California), "Coulomb Barrier Transmission Resonance Transparency for Cold Fusion with Deuterium and Hydrogen," presented at ICCF4.

AUTHORS' ABSTRACT

Recently, Kim and Zubarev developed a general and realistic barrier transmission model which can accommodate simultaneously both non-resonance and Coulomb barrier transmission resonance contributions. The resonance transparency (RT) model will be presented and its implications for cold fusion will be discussed.

Previous low-energy (< 20 kev) cross-section $\sigma(E)$ used in nuclear fusion rate calculations are calculated by extrapolating the experimental values of $\sigma(E)$ at higher energies using the parametrization

$$\sigma(E) = \frac{S(E)}{E} T_G(E) \qquad (1)$$

where $T_G(E) = \exp[-(E_G/E)^{1/2}]$, $E_G = (2\pi\alpha Z_1 Z_2)^2 \mu c^2/2$ with the reduced mass $\mu = m_1 m_2/(m_1 + m_2)$ and $E$ is the center-of-mass (CM) kinetic energy. The transmission coefficient ("Gamow" factor) $T_G(E)$ results from the approximation $E << B$ (Coulomb barrier height). Note that $\sigma(E)$ described by eq. (1) is valid only for non-resonance fusion reactions.

In order to accommodate more realistic transmission coefficients, we write a more general parametrization for $\sigma(E)$ as

$$\sigma(E) = \frac{\tilde{S}(E)}{E} T_{KZ}(E) \qquad (2)$$

where $T_{KZ}(E)$ is the new transmission coefficient for the fusing system which has an interior square-well nuclear potential and an exterior Coulomb repulsive potential,

$$V(r) = \begin{cases} -V_0, & r<R \\ Z_1 Z_2 e^2/r, & r \geq R \end{cases} \qquad (3)$$

For the potential described by eq. (3), a general solution for the exterior wave function in the exterior region ($r \geq R$) is a linear combination of the regular and irregular Coulomb wave functions, $F_\ell(r)$ and $G_\ell(r)$, respectively. For the interior region ($r \leq R$), a general solution for the interior wave function is

$$u^{int}(r) = e^{iKr} + c\, e^{+iKr} \qquad (4)$$

where $\hbar^2 K^2/2\mu = V_0 + E$ with $E = \hbar^2 k^2/2\mu$. We introduce two parameters $\tau$ and $\phi$ and write $c = \tau e^{i\phi}$, ($\tau<1$). Using the boundary condition at r = R, we obtain the barrier transmission coefficient $T_{KZ}(E)$ for the $\ell = 0$ case[1]:

$$T_{KZ}(E) = \frac{4 s_0 \bar{K}_1 R}{|(\Delta_0 + i s_0) - (\bar{K}_2 R - i\bar{K}_1 R)|^2} \qquad (5)$$

where $s_0 = R[G_0F'_0 - F_0G'_0 / (G_0^2 + F_0^2)]_{r=R}$, $\Delta_0 = R[(G_0G'_0 + F_0F'_0) / (G_0^2 + F_0^2)]_{r=R}$, $K_1(E, \tau, \phi) = K(1-\tau^2) / [1+2\tau \cos(2KR + \phi) + \tau^2]$ and $K_2(E, \tau, \phi) = -2K\tau \sin(2KR + \phi) / [1 + 2\tau \cos(2KR + \phi) + \tau^2]$. $T_{KZ}(E)$, eq. (5), is described by four parameters, $V_0$, R, $\tau$, and $\phi$, which can be determined from the cross-section containing both a resonance part (resonance energy and width) and a non-resonance background. The resonance behavior of $T_{KZ}(E)$, generated from fitting $\sigma(E)$ with particular values of parameters, is an RT due to an interplay of the transmitted and reflected waves involving both Coulomb barrier and nuclear interaction, and is to be distinguished from the conventional resonances such as narrow neutron capture resonances, which is primarily due to the nuclear interaction.

$T_{KZ}(E)$ has a Breit-Wigner form when $(\Delta_0 + is_0)-(K_2R - iK_1R) = 0$ at a pole $E = E_R - i\Gamma/2$ in the complex E plane. The resonance

energy $E_R$ and width $\Gamma$ are determined by the parameters $\tau$ and $\phi$ for fixed values of $V_0$ and R. If an RT exists, $T_{KZ}(E) \approx 1$ and $T_{KZ}(E) >> T_G(E)$ at the pole, the Coulomb barrier becomes nearly transparent and hence cold fusion can occur, in contrast to the common belief, based on the conventional Gamow formula that cold fusion is impossible since $T_G(E)$ in eq. (1) is vanishingly small at ambient temperature. Even though $\Gamma$ may be extremely small when $E_R$ is near the threshold energy, the fusion rate can be shown to be still large for $T_{KZ}(E_R) \approx 1$ in a non-equilibrium situation. In spite of this extremely narrow resonance which does not result in appreciable equilibrium fusion, energy sweeping through the resonance energy results in a greatly enhanced fusion rate. This may explain why perturbations are necessary to achieve cold fusion. In view of the new result for $T_{KZ}(E)$, eq. (5), we must now ask whether some fusing systems can support an RT at low energies near the fusion threshold, which can be answered at present only by experiments. It should be emphasized that RT cold fusion is possible not only with deuterium but also with hydrogen since $T_{KZ}(E)$, eq. (5), is applicable to both cases as long as the RT exist in fusing systems involving deuterium or hydrogen, such as in nuclear fusion reactions with the entrance channels, *D + D, D + Li, D + Pd, H + D, H + K,* etc.

Given the RT mechanism for cold fusion the question remains why fusion products are observed in cold fusion experiments at a much lower level than commensurate with the observed excess heat. This question can only be addressed separately for each fusion reaction since the exit channels are different for each reaction. For example, D + D fusion may proceed with $D(D, e^-e^+)^4$He channel rather than $D(D,\gamma)^4$He if an RT state exists as an excited $0^+$ state of $^4$He near the fusion threshold energy. Transition $0^+ \rightarrow 0^+$ (ground state) is forbidden for $D(D,\gamma)^4$He but allowed for $D(D,e^-e^+)^4$He. Once $T_{KZ}(E) \approx 1$ is achieved by the RT mechanism, the fusion rate for $D(D, e^-e^+)^4$He can be substantially larger than the conventional estimate even though the decay width for the exit channel is small (~ 1.4 x $10^{-2}$ Ev). This scenario and others such as $^6$Li(*d,p*), $^7$Li, $^7$Li(*d*,$^4$He)$^5$He, etc. may explain the results of excess heat, tritium and neutron productions observed in heavy water (with Li) electrolysis experiments. Possible scenarios for other cases involving both deuterium and hydrogen such as $^{39}$K($p,e^-e^+$)$^{40}$Ca, etc. will be discussed.

## INDIANA - DEE'S 1934 EXPERIMENT

Yeong E. Kim (Dept. Phys., Purdue Univ., West Lafayette, IN), "Dee's 1934 D-D Fusion Experiment and Possible Evidence for Cold Fusion," presented at ICCF4.

AUTHOR'S ABSTRACT

In 1934, Oliphant, Harteck, and Lord Rutherford reported the discovery of deuterium-deuterium fusion via nuclear reaction, D(D,p)T and D(d,n) $^3$He. They bombarded deuterated ammonium chloride ($ND_4Cl$), ammonium sulphate ($(ND_4)_2SO_4$) and orthophosphoric acid ($D_3PO_4$) with a 20 ~ 200 keV deuterium (called "diplogen" then) ion ($D^+$) beam generated from a Cockcroft-Walton discharge tube. Later in the same year (1934), Dee studied the nuclear reaction D(D,p)T more carefully using a 160 keV $D^+$ beam on a $(ND_4)_2SO_4$ target, and photographed ionization tracks of p and T in a cloud chamber. Occasionally, proton-tritium (p-T) pairs were observed with the angle between the tracks very near to 180º. Dee attributed these tracks to D(D,p)T reactions involving deuterons which have lost energy by collisions in the target. The expansion chamber detection system used by Dee was developed earlier by Dee and Walton. The $D^+$ beam generation system used by Dee was an improved Cockcroft-Walton discharge tube constructed by Oliphant and Rutherford which generated a higher $D^+$ beam current (~100µA). Recently, Fleischmann suggested that these results obtained by Dee are the first indication that there are low energy fusion channels in solid lattices as in the case of the cold fusion electrolysis experiments. Fleischmann's suggestion was criticized by Close on two grounds. First is that Dee's photographs do not show that the tracks are exactly back-to-back and hence one cannot eliminate the possibility that the incident deuteron had even one keV of energy, which is comparable to the solar core temperature. The second objection by Close was that no energetic tritium or proton had been observed in the cold fusion electrolysis experiments with deuterated palladium. More recently, Huizenga objected to Fleischmann's statement that *a significant number* of back-to-back tracks were observed by Dee, since what Dee actually stated was that *occasionally* back-to-back p-T tracks were observed.

In this paper, Dee's results are analyzed using the conventional theory to establish whether the back-to-back p-T tracks observed by Dee suggest an anomalous effect, in order to resolve the controversy between Fleischmann's suggestion and its objections by Close and Huizenga.

It is shown that the conventional theoretical estimates can not explain the back-to-back pT tracks observed by Dee. Therefore, the suggestion made by Fleischmann that Dee's back-to-back pT tracks are the first indication of cold fusion may have a validity, in contrary to the objections raised by Close and Huizenga.

One plausible explanation of Dee's data for the back-to-back pT tracks, based on a general and more realistic solution of the transmission coefficient $T_{KZ}(E)$ by Kim and Zubarev, is that the Coulomb barrier transparency exists for the transmission coefficient near the fusion threshold energy. The conventional Gamow transmission coefficient, $T_c(E)$, is restricted to non-resonant reactions, and hence can not describe such resonant behavior of the transmission coefficient. In other conventional theoretical models, Breit-Wigner (BW) resonances are included in the S-factor, S(E), in $\delta(E) = S(E)T_G(E)/E$, but any enhancement of the cross-section $\delta(E)$ due to the BW resonance is limited to at most a few orders of magnitude increase and hence cannot explain the Dee's data. Therefore, it is important to repeat Dee's experiment with modern facilities and techniques. The use of deuterium bubble chamber with pulsed incident deuteron beams is most promising, and may lead to a definitive test of Dee's anomalous back-to-back pT tracks.

## INDIANA - DEEP DIRAC STATES

R.A. Rice, Y. E. Kim (Dept. of Phys., Purdue Univ., West Lafayette, IN) and M. Rabinowitz (EPRI, Palo Alto, CA), "Comments on Exotic Chemistry Models and Deep Dirac States for Cold Fusion," presented at ICCF4.

AUTHORS' ABSTRACT

A number of models assume the existence of an exotic chemical system whose occurrence either precedes nuclear synthesis or makes it quite unnecessary. The similarity of these postulated models is in their tight binding of electrons in atoms and/or molecules. In one of the simplest, the authors claim that in addition to the normal energy levels for the H atom, a more tightly bound sub-ground state of -27.21 eV is possible. For them, the excess Cold Fusion (CF) power, with no nuclear products, is simply the extra 13.68 eV/atom obtained as H isotopes go into the sub-ground state. If their "tight H" abounds in the universe, one may ask why this spectral line has not been seen long ago.

The next set of models involve "tight H" isotope molecules of radius ~ 0.25 Å in which excess energy may result chemically, and/or from nuclear fusion as the tightly bound atoms more easily penetrate their common Coulomb barrier. Actually, there seems to be no sound basis for assuming the existence of a superbound state of a $D_2^+$ ion. Some of the analysis is qualitative. The most critical region is barely at the boundary of applicability of the equations. An exact solution for the entire region under consideration will likely yield a potential with no local minimum. Thus the metastable state may not be present in a more rigorous analysis. Therefore, the superbound solution is at best unstable.

Gryzinsky and Barut present analyses to substantiate the existence of the metastable $D_2^+$ state based on three body calculations for two d's and one electron. Gryzinsky treats the problem mainly classically, but neglects radiation effects for his oscillating electron as allowed by quantum mechanics. Barut's analysis is based on the Bohr-Sommerfeld quantization principle, and obtains a binding energy of 50 keV. Both authors, independently, conclude that a "superbound" $(D_2^+)^*$ molecular ion can exist in which an electron that is exactly half-way between the d's provides an attractive force and screens the d Coulomb repulsion. Vigier presents an analysis almost identical to that of Barut. For Barut, Gryzinsky, and Vigier, the analysis is predicated on very unlikely precise symmetry. The electron must be exactly the same distance on a line between the two d's. The tightness of the orbit appears to violate the uncertainty principle. Although a non-relativistic analysis may be warranted for the large mass H isotopes around the electron, a nonstationary electron will require a relativistic treatment because it will attain a velocity close to the velocity of light due to its small mass. Perhaps a full relativistic calculation including spin-spin and spin-orbit coupling may save this model, but this has not been presented as yet.

Mayer and Reitz claim that resonances of ep, ed, and et are created which if they survive long enough, allow a high probability of barrier penetration and subsequent nuclear reaction. Their resonance model is based on that of Spence and Vary who used single photon exchange in Coulomb gauge. Recently McNeil reformulated the ep problem in a qualitative yet gauge-invariant way and finds no evidence for a resonance in the ep system in the energy range of interest. Therefore, it is possible that the results of Spence and Vary and hence Mayer and Reitz are spurious.

Most recently, Maly and Va'vra carried out a calculation for the hydrogen atom based upon irregular solutions of the relativistic Dirac equation and obtained an extremely tightly bound electron orbit. They get a binding energy ~ 500 keV, and a radius of ~ 5 X $10^{-13}$ cm, a nuclear dimension. For them CF also involves no nuclear process. The excess energy is 500 keV/atom as these tightly bound atoms are formed. They suggest that this chemical ash of tightly bound H or D atoms may account for the missing mass (dark matter) of the universe. However, there are some serious errors in their analysis. At the nuclear surface, $r = r_n \neq O$, both regular and irregular solutions are allowed simultaneously for $r \geq r_n$. Therefore, a general solution is a linear combination of them for $r \geq r_n$. When the boundary conditions are imposed at $r = r_n$, it can be shown that the irregular component becomes nearly negligible compared to the regular component. The results of Maly and Va'vra are incorrect, since they assumed erroneously that the irregular solution is a general solution independent of the regular solution.

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**MASSACHUSETTS - MANY-BODY THEORY**

Peter Hagelstein and Sumanth Kaushik (Res. Lab. Electr., MIT, Cambridge, MA), "Delocalization of Virtual Neutrons," presented at ICCF4.

AUTHORS' ABSTRACT

A many-body theory for neutron transfer reactions has been developed that describes nuclei, a lattice, and free neutrons (using a Hamiltonian $H_0$); and transitions of neutrons between bound states and free states (through the interaction Hamiltonian *V*).

The ground state of the coupled system can be studied using an approximate model in which it is assumed that at most only one neutron is free at a time. In this approximation, we seek to solve

$$\left[\frac{\hat{H}_0 \;\; \mathbf{0}}{\mathbf{0} \;\; \hat{H}_0}\right]\left[\frac{\Psi_0}{\Psi_1}\right] + \left[\frac{\mathbf{0} \;\; \hat{V}}{\hat{V} \;\; \mathbf{0}}\right]\left[\frac{\Psi_0}{\Psi_1}\right] = E\left[\frac{\Psi_0}{\Psi_1}\right]$$

where $\Psi_0$ refers to the situation where no free neutrons are present, and where $\Psi_1$ refers to the situation where a single free neutron is present.

Using infinite-order Brillouin-Wigner perturbation theory, we are able to determine the ground state energy *E* of the coupled system from knowledge of the ground state wavefunction $\Phi_0$ of the unperturbed system that satisfies

$$H_0\Phi_0 = E_0\Phi_0$$

The Brillouin-Wigner expression for the ground state energy is

$$E = <\mathbf{\Phi_0}|\hat{H}_0|\mathbf{\Phi_0}> + <\mathbf{\Phi_0}|\hat{V}\left[E - \hat{H}_0 - \hat{V}(E-\hat{H}_0)^{-1}\hat{Q}\hat{V}\right]^{-1}\hat{V}|\mathbf{\Phi_0}>$$

The ground state of the coupled system is found to be the Dicke state with maximum coherence relative to site occupation. This state also possesses a considerable free neutron contribution; the free (virtual)

neutron component is found from Brillouin-Wigner perturbation theory through

$$\left[ E - \hat{H}_0 - \hat{V}(E - \hat{H})^{-1}\hat{Q}\hat{V} \right] \Psi_1 = \hat{V}\Psi_0$$

This equation exhibits explicitly coherent resonant exchange scattering effects that were proposed at the Nagoya meeting.

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**MASSACHUSETTS - HYDROGEN ENERGY**

K.H. Johnson (Dept. of Mat. Sci., MIT, Cambridge), "Symmetry Breaking and Hydrogen Energy in $PdD_x$," presented at ICCF4.

AUTHOR'S ABSTRACT

In a 1989 publication Johnson and Clougherty proposed a common quantum-chemical origin of superconductivity and anomalous electrochemical properties of palladium loaded with hydrogen and deuterium, based on the presence of delocalized interstitial H-H/D-D bonding molecular orbitals at the Fermi energy ($E_F$). Highly non-linear symmetry-breaking dynamic Jahn-Teller vibrations of the protons/deuterons, induced by the H-H/D-D molecular-orbital degeneracy at $E_F$, promote Cooper pairing and superconductivity in $PdH_x/PdD_x$ ($x \approx 1$) below $T_c$ = 9-10°K, while the large vibronic anharmonicity explains the inverse H/D isotope shift of $T_c$ and departure from *BCS* theory. Dynamic Jahn-Teller-induced deuteron vibronic amplitudes up to 0.5Å were calculated, leading to a maximum D-D approach of 0.7Å and an upper limit of $5x10^{-24}$ fusion per deuteron pair per second in $PdD_x$ at room temperature for high loading ($x \approx$ 1). This calculated fusion rate in PdD, although much greater than that ($10^{-70}$) of free $D_2$ molecules and consistent with the low levels of neutrons reported in cold fusion experiments, is much too small to explain the "excess" heat energy (at least 10eV per Pd atom) claimed in some of these experiments.

In this paper, I present the results of recent state-of-the-art *ab initio* quantum-chemical computations for the potential energy surface of $PdD_x$, at high loadings ($x \geq 1$), and their implications on heat production. For loadings of $x \approx 1$, the sole occupation of octahedral interstices is Jahn-Teller unstable toward migration of D's to tetrahedral interstices, resulting in degenerate D-D bonding molecular orbitals between neighboring tetrahedral sites at $E_F$. A wavefunction contour map for one of these orbitals, plotted in a (110) plane, is shown. The "compression" of the tetrahedral-site D(1s) orbitals by nearest-neighbor antibonding Pd(4d) and remaining octahedral-site D(1s) orbitals promotes D(1s)-D(1s) σ-bond overlap and relaxation between tetrahedral interstices. The corresponding D-D potential energy surface in Pd, resembling a "Mexican hat", is shown schematically. The high-symmetry (Td) coordination of a Pd atom by D atoms in four of the eight surrounding free-palladium tetrahedral interstitial sites is Jahn-Teller unstable, leading to a central energy minimum of distorted tetrahedral ($C_{3v}$) symmetry and a planar ($D_{2h}$) "broken-symmetry" energy minimum 9.4eV below Td symmetry at a shortened D-D distance of 0.76Å. The latter is practically equal to the 0.74Å bond distance of a free hydrogen molecule. The 9.4eV energy per Pd atom released in the Jahn-teller distortion of each $PdD_4$ cluster from Td to $D_{2h}$ symmetry is likewise remarkably close to the sum of the chemical bond energies (4.75eV) of two free hydrogen molecules. **Thus, for high loading, the tetrahedral interstices of palladium provide, via the Jahn-Teller effect, an "orbital pathway" for the bulk catalytic recombination of rapidly diffusing D atoms to $D_2$ "molecules", the large chemical heat of recombination approaching 10eV per Pd atom**. This mechanism may also explain reported heat generation in light water electrochemical cells using nickel electrodes, where the catalytic recombination of hydrogen is mainly a (110) surface phenomenon. Heat production in light water electrochemical cells was originally predicted by Johnson and Clougherty in 1989.

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**MASSACHUSETTS - STEADY-STATE HEAT**

Mitchell R. Swartz (JET Tech. Weston, Massachusetts), "A Method to Improve Algorithms used to Detect Steady State Excess Enthalpy," presented at ICCF4.

AUTHOR'S ABSTRACT

In the literature there are several methods for analyzing data to determine excess enthalpy. When the method depends upon dynamic changes of a key parameter, either an expanding, or sliding, window can be used to derive information. Sliding windows have been used to reevaluate one key "negative" cold fusion experiment [Harwell] demonstrating the appearance of excess enthalpy previously not reported. The impact of the expanding vs. sliding window algorithms will be reexamined. Examination of hypothetical excess enthalpies by these algorithms indicates that a distinct data pattern can appear ("reverse-Z") when an improper algorithm is used in the presence of excess enthalpy. Most importantly, an improper algorithm may make an experiment simply insensitive to any steady state (DC) excess enthalpy produced. A second example of sliding window reevaluation providing the possibility of excess heat in a supposed "negative" experiment, accompanied by the "reverse-Z" pattern, will be discussed.

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**MASSACHUSETTS - LESSONS FROM PFC**

Mitchell R. Swartz (JET Technology, Weston, Massachusetts), "Some Lessons from Optical Examination of the PFC Phase-II Calorimetric Curves," presented at ICCF4.

AUTHOR'S ABSTRACT

Since 1989, electrochemically-induced excess enthalpy reactions using palladium filled with deuterons from heavy water have been very difficult to reproduce. Because of those difficulties cold fusion incorrectly connotes a "failed" technology in the minds of many scientists -- even as the positive literature grows. Many skeptics cite the published Phase-II data from the Massachusetts Institute of Technology Plasma Fusion Center [PFC]. Scientific criticisms of the PFC data and techniques have included faults with its thermal calculations and purported differences in curves. This independent examination has revealed that several different curves purported by the PFC to be the result of a single Phase-II heavy water experiment

in 1989. Type 1 curves are the raw heater power data. A baseline shift of circa 900 nanowatts/second was applied to the Type 1 curve to get the Type 2 curve. A second circa 94 nanowatts/second shift was applied to generate prototype 3. The superposition of additional points (e.g. point "A"), not present in either the Type 1 or Type 2 curves, completes the transformation to the Type 3 curve. This paper discusses both the transformation from the Type 2 to Type 3 curves which were published (Type $3_B$) and other curves in further detail.

An attempt was made to determine what algorithm(s) were used to process the curves. A linear model was used to determine the transformations used: Type 2 + [A+(B*t)]---> Type 3. The figure shows the superposition of the low-pass fit curve with four linear baseline shifts [A=O]. The published heavy water data of the PFC is also shown as the darkest dots and thicker line on the left hand side. The darker gray continuous curve (with the greatest time-varying baseline shift) shows the superposition of A=O and B= -158 nanowatts/second upon the low-pass curve. Other observations and suggestions will be presented.
[See figures in Swartz article *FF* Aug. 1992]

## MASSACHUSETTS - EMBEDDED ATOM MODEL

Irfan Chaudhary, Sumanth Kaushik, Keith Johnson and Peter Hagelstein (M.I.T., Cambridge, Massachusetts), "Embedded Atom Models for PdD and Applications," presented at ICCF4.

AUTHORS' ABSTRACT

The embedded atom model has been successful for providing a simple and accessible description of atom-atom interaction in solids. This type of model has been recently applied to molecular dynamics simulations of PdD, and has also been used to study quantum diffusion in PdH. The premise of the embedded atom model is that the energy of a single atom in a solid is determined to lowest order from (1) the local electron density due to neighboring atoms and (2) short range screened Coulombic repulsion between atoms. An embedded atom model based on such a premise provides a description that is qualitatively correct for deuterium in dilute Pd.

Extended or modified embedded atom models are sometimes developed in order to provide improved agreement with observable, such as elastic constants or optical frequencies. We compare the embedded atom model with results from *ab initio* Hartree-Slater electronic calculations on clusters of PdD, and explore modifications of the model to provide improved agreement with equilibrium force constants and relative octahedral to tetrahedral site energies.

We consider the application of the embedded atom model to PdD, and examine the utility of the model for applications to problems that arise in cold fusion studies.

## MICHIGAN - HOME EXPERIMENT

Mark Hugo (Northern States Power Co., Minneapolis, MN), "A Home Cold Fusion Experiment--Is it Real, or Is it the CF Hex?," presented at ICCF4.

AUTHOR'S ABSTRACT

Three years of experiments have seen a home Cold Fusion experiment go from a kluge of epoxied baby feeding bottles, Radio Shack indoor/outdoor thermometers, and the cheapest CC power supplies to a much more sophisticated CF cell fabricated by the U. of M. Also a multi-channel personal computer data gathering device, a sensitive (courtesy of Tom Droege) temperature sensor for delta-T measurements, a precise chemical metering pump are now in operation. Evidence is now available to suggest that the author may have a guaranteed method of obtaining the P&F effect in the 10 to 30% excess range (in the 10-15 watt input range) within a 60 hour start up period. Presentation of data, set up, and discussion of possible errors will be made, along with details needed for replication.

## MICHIGAN - BOSON CONDENSATION

James T. Waber (Phys. Dept., Mich. Tech. Univ. Houghton, Michigan), and Manuel de Llano (Phys. Dept., N. Dakota St. Univ., Fargo, North Dakota), "Boson Condensation in the Solid State Within a Sea of Fermions as a Model for Cold Fusion," presented at ICCF4.

AUTHORS' ABSTRACT

In an earlier paper, the idea of boson condensation was presented as a method of predicting the primary products of the cold fusion and understanding how two deuterons in a solid medium might fuse. The connection with superfluidity and superconductivity was stated, since they involve bosons. One essential ingredient was the possibility of Born-Oppenheimer separability of the nucleonic and electronic functions and the second was the reformulation of the electronic wave functions in the Wannier representation. The problem is here recast relying on the recent modification of BCS theory of superconductivity for high $T_c$ materials by Fujita.

Since a metal such as palladium (or palladium hydride) are on the whole electrically neutral even though they are electric conductors. The Coulomb interactions between electrons and the ion cores are equal and to a large extent cancel each other out. If we take a specific electron, then it interacts with the system of N ions and N-1 electrons; the system has a net charge of +e. This is a rephrasing of the statement of Chubb and Chubb. They pointed out that such an electron when treated by the Bloch theorem is spread out over the entire solid and only a tiny fraction of it would be contained in any lattice cell. The other consequence is that any energy produced by coalescence or reaction between band state "particles" would similarly be distributed over the whole solid. They are in or near equilibrium. The important point is that the interaction strength of

this electron or particle is greatly reduced by the screening of the N-1 electrons in the system.

We are led to energy bands $\epsilon_n(K)$ and Bloch states, labelled by a band index n and a wave vector K with three Cartesian components. Each such band state has both ↑ and ↓ spins associated with it, i.e., is two-fold degenerate. The Bloch electron (or particle) obeys Fermi-Dirac statistics independent of any interaction.

If the particle is in a field of phonons, a pair of Bloch particles can interact by exchanging phonons thus lowering their energy. Earlier, Yukawa pointed out that nucleons, either neutrons or protons, could experience attraction by exchanging pions. It is a similar process since both cases involve interactions with bosons.

It is postulated here that near the Fermi Level an instability occurs from phonons which leads to Cooper pairs of electrons and as well as a deuteron Cooper pairs of deuterons in band states. (Each deuteron has a spin paired neutron and proton yielding total spin 1 and thus is a boson). If the distance between the centers of mass of either type of pair is large, the effective Coulomb interaction is reduced to the Debye-Huckel screened potential.

Fujita and Watanabe (who used electron holes as the positive charge carrier) postulate that the Coulomb interaction generates a correlation among (but not between) the pairs of negative and positive charge and thus modified BCS theory. They allow different individual correlation strengths, and lifted the restriction on equal momenta. The unequal Interactions and unequal momenta have interesting consequences. One can infer good equations of motion diagonalized in a net momentum **q**. The Cooper pairs, both above and below the condensation temperature $T_c$, move independently because the net momentum **q** is a constant of motion. The wave functions Ai(**k,q**) are coupled with respect to **q**. This implies according to Fujita that the true wave function is a superposition of "electron" and "hole" or "deuteron" pair plane wave functions. The energies of the excited Cooper pairs form a continuous energy band. Chubb and Chubb called these ionic band states (IBS) and a Boson-Bloch-Condensate (BBC).

The conditions for the separability of the "superimposed" wave function still applies. Fujita's theory accounts for the coherence distance of the electronic Cooper pair in high $T_c$ being about 10 Å instead of the familiar 10,000 Å. The deuteronic boson condensation temperature can be estimated to be 8,000°K. We estimate the equivalent size for the Cooper deuteron pair to be 50 Fermis. The net charge on these pairs $2e(Q_e + Q_d)$ is distributed throughout the crystal and the electrostatic repulsion greatly reduced by rearrangement of the electrons and ion in the bulk crystal. We propose that the proximity of the paired D+ ionic band states become the precursor of $^4$He ionic band states with the energy release spread over the crystal. So fusion of the two D+ bosons becomes quite feasible.

## MICHIGAN - RELATIVE BAND STRUCTURE

James T. Waber, Warren Perger (Phys. Dept. and E.E. Dept., Michigan Tech. Univ., Houghton, Michigan), and Ralf Schleitzer (Phys. Dept., Univ. Leipzig, Germany), "Relativistic Band Structure Calculation of Palladium Hydride," presented at ICCF4.

AUTHORS' ABSTRACT

The band structure of palladium hydride has been studied nonrelativisitcally by several authors. But the effects of relativity has not been assessed. Switendick used the ground state of palladium metal, namely $4d^9$ $5s^1$ but Papacontantopoulus et al. used $4d^{10}$ $5s^0$. Inspection of the various band structures show that the configuration in the metal is approximately $4d^9$ $5s^1$ although the self-consistent band structure calculations may yield non-integral values.

Two effects were to be expected. The direct effect on the s-p bands which would lower them and the indirect relativistic effect on the d bands, which would tend to raise them because of the greater screening of the nuclear charge. An additional but small effect of lifting several threefold degeneracy of points like $\Gamma_{25}'$. Because of the significant s-participation in the electronic structure, it is difficult to determine which effect on the Fermi Surface will dominate a priori. Waber et al. showed that small changes in the assumed configuration of nickel $3d^{10-X}$ $4s^x$ produced changes in the topology of the Fermi Surface particularly near point L in the Brillouin Zone.

Switendick investigated the effect of adding hydrogen atoms to the interstices of FCC palladium i.e., of increasing x. The s-p states were anti-bonding and as x went from 0 to 2 stepwise the Pd d-bands fell with respect to zero potential of the free atom. [This was used since the more conventional choice $\Gamma_1$ for zero since the latter varies significantly from compound to compound.] Papacontantopoulus also showed that the density of states at the Fermi level $N(E_F)$ fell to a low value with increasing occupation. Thus it becomes "costly" energy-wise to add hydrogen atoms. Defects arise to reduce the elastic strain as well as the energy cost. In an accompanying paper, we propose the two types of bosonic Cooper pairs form as a result of the interaction with optical phonons. It should be noted that such pairs only form readily when the Fermi Level comes into the immediate vicinity of the Brillouin Zone. The positively charged D+ pair are the analogue of electronic holes in the conventional BCS superconductivity theory. Chubb labels these as ionic band states (IEBS) and the collection, the Boson-Bloch-Condensate (BBC). The present modification of Fujita's theory offers an explanation why x must approach unity before a significant amount of fusion occurs. When x is small, empty states in the d-band of palladium are the first to be occupied. Subsequent hydrogen atoms lower the d-bands of the palladium as well as the hydrogen-derived states. Insufficient hydrogen is equivalent to the Fermi Surface being too distant for the $D^+$ boson pair to form.

As Fujita points out, sodium and other monovalent metals do not become superconductive since the Fermi level is too far away from the Brillouin Zone for Cooper pairs of holes to form. This has implication for fusion experiments using alkali metal elements in light water.

We started with $d^9$ $s^1$ calculated using the Liberman-Waber-Cromer program for the atomic charge density with the exchange value of 2/3. This was used in Louck's relativistic APW program.

The results are compared with the Fermi surface of $PdD_x$ and $PdH_x$ determined from de Haas-van Alpen measurements by Bakker et al. The pockets at $X_4$' were observed to be the most influenced by the isotopic mass, when comparing H with D.

## MISSOURI - THERMOELECTROCHEMICAL EFFECT

Peter H. Handel (Phys. Dept., Univ. of Missouri, St. Louis), "Subtraction of a New Thermoelectrochemical Effect from the Excess Heat, and the Emerging Avenues to Cold Fusion," presented at ICCF4.

AUTHOR'S ABSTRACT

Electrolytic cells are shown to work like heat pumps, pumping in an infinite amount of environmental heat per 1 Joule of excess energy supplied, for a vanishing temperature difference between the hot and cold sources, in the reversible limit of arbitrarily low current densities. In practical situations, the finite temperature difference between the electrolyte and the colder outside connections of the electrodes to copper wires, as well as the irreversibility caused by the finite current density and by the resulting electrode overpotentials impose strict limits on the thermoelectrochemical excess heat. The present paper indicates how this extraneous excess heat can be calculated and subtracted from some of the experiments performed to date, how it can be automatically compensated or subtracted in future experiments, how it contributed to the notorious irreproducibility of past excess heat, and how it can obscure or distort the true excess heat present in the experiment. The best practical way to compensate or avoid the heat pump effect is the inclusion of the external connections of the anode and cathode to a pair of identical copper wires into the calorimeter, far enough inside from the calorimeter wall. Moreover, the paper examines three ways of enhancing the effective energy balance in cold fusion reactors. The first way considered is an increase of the otherwise utterly negligible neutron transfer rates due to closer approach of deuteron pairs, caused by very large wave-number dependent effective masses in some rare earth compounds. An experiment which is designed to measure the resulting rate of tritium generation is underway since the spring of 1992. The second way considered is based on the isolation of certain vibration modes in resonant particle traps, or in atomic lattices, to minimize coupling to other modes, and on advanced methods of retrieving the escaped energy. The third way tries to increase muon-catalyzed fusion rates and single-muon cycle lengths through many-body effects and additional resonances, bringing the energy balance closer to break-even. The paper indicates that the potential of cold fusion for practically solving the problem of controlled nuclear fusion is not inferior to the promise of magnetically confined or inertial plasma fusion.

## NEW MEXICO - DEUTERON-INDUCED FUSION

G.M. Hale, and T.L. Talley (Theor. Div., Los Alamos Nat. Lab., Los Alamos, New Mexico), "Deuteron-Induced Fusion in Various Environments," presented at ICCF4.

AUTHORS' ABSTRACT

The theory of deuteron-induced fusion will be discussed, first in free space, then in muonic molecules where the Coulomb repulsion is highly screened. It will be shown how a consistent description of the d+d and d+t reactions can be obtained in these environments using R-matrix theory. We will derive an expression for the fusion rate from time-dependent scattering theory, and see how it compares with Jackson's famous formula for the case of d-t fusion in a muonic molecule.

Finally, some speculative comments will be made about how these reactions might proceed in other media, such as metallic lattices. We emphasize that the same methods can, and should, be used to describe this situation as well as the other two well established phenomena. We will discuss whether these methods then allow any hope of explaining the observations made in cold fusion experiments, and make suggestions for further observations that may "pin down" the nature of the reaction(s) that may be occurring.

## NEW MEXICO - NEUTRONS FROM HIGH CURRENTS

Stuart F. Taylor, Thomas N. Claytor (Los Alamos Nat. Lab., Los Alamos, New Mexico), and Steven E. Jones (Dept. Phys. and Astro., BYU, Provo, Utah), "Detection of Neutrons from Deuterided Palladium Subject to High Electrical Currents," presented at ICCF4.

AUTHORS' ABSTRACT

Tritium has been detected being produced in cells of deuterided palladium wires and powders put under pulsed high voltage at Los Alamos. We wanted to measure if these same cells were producing neutrons. The idea of pulsing current through the wires and powders was to drive the deuterium in and out by electrical heating. With promising tritium results in hand, the experiments were prepared at Los Alamos, and then taken to BYU and run in our neutron detector located in a tunnel in Provo canyon under 80 m minimum of rock and dirt overburden.

The neutron detector at BYU is referred to as a "modified Jomar detector" because it is a helium-3 tube detector designed at Los Alamos and produced by the Jomar corporation with a plastic scintillator placed in the cylindrical cavity of the Jomar detector. The efficiency of the Jomar helium-3 detector alone is 34%, and the efficiency of the plastic scintillator is 48%, for a combined efficiency of 16%. Three plastic scintillator veto counters around the detector greatly reduce the cosmic ray background; with the veto counters in place, the efficiency of the modified Jomar detector is near 15%. In this tunnel, the background rate in the helium-3 detector is about 85 counts per hour. When combined with the plastic scintillator, the modified Jomar detector has a background count rate of 0.45 detected neutrons per hour when we require a more strict time correlation and a more narrow plastic scintillator pulse area range, and about 0.7 per hour when we relax these criteria slightly. Approximately once every 30 hours we record a detection event that we refer to as a "multiple" count, which is an event indicative of more than one neutron being detected by the helium-3 counter within 160 microsecond window.

When the time distribution of how long after the plastic pulse the helium-3 counter detects a neutron are histogrammed for a plutonium source, the result is an exponential decrease. in contrast, when this time distribution is histogrammed for the counts from a hydrogen background, the distribution is closer to being flat, indicating less correlation between the plastic and the helium-3 signals. When these multiple counts are plotted for the runs where deuterium was being forced out of the palladium, the distribution looks to be a mix of a flat distribution and an exponential decrease, indicating a possible source component to this signal.

A rough idea of the energies of the neutrons that produced a start pulse in the plastic scintillator can be obtained. The total amount of scintillation of the pulse produced by the neutron, called the area of the pulse, is proportional to the amount of energy deposited by the neutron in the scintillator, which is an unknown fraction of the neutron's energy. Thus neutrons of a single energy would produce a characteristic distribution of areas. The distribution of the foreground and background runs were plotted and compared. The small number of neutrons detected do not yet produce a very smooth distribution of the areas in either the foreground or the background; when the events in which a single neutron is detected in the helium-3 tubes are plotted it is not apparent whether there is a significant difference between the two distributions. The number of multiple events is 18 doubles and one triple in the 260 hours of foreground and 7 doubles plus one triple in the 260 hours of background. In 130 hours with a cell containing deuterium but not subject to current (called a "stable" cell) there were 3 doubles. Perhaps most significant is that all 8 multiples in the background have a plastic pulse area less than 800, but 8 of the 19 multiples in the foreground have plastic pulse areas greater than 800. In the stable cells, there were 2 multiples with area below 800, one above. Further analysis of the relative distributions of the plastic pulse areas of multiple events will be presented.

## UTAH - HIGH PRECISION CALORIMETRY

Steven C. Barrowes and Haven E. Bergeson (Phys. Dept., Univ. Utah), "Linear, High Precision, Redundant Calorimeter," presented at ICCF4.

AUTHORS' ABSTRACT

A precision calorimeter has been built for measuring the heat output from closed electrochemical cells typically containing deuterated palladium cathodes. The calorimeter simultaneously measures heat flow by two independent methods: a voltage output due to the Peltier effect and a temperature difference noted by platinum RTDs on inner and outer walls of the calorimeter. Four calorimeters are run in a common water bath controlled to ±0.01°C. Two of five planned baths are now running.

The calorimeter was designed to conduct over 90% of the heat flow through 12 thermoelectric devices (Melchor type CP-I.4-127-O45L-2) and to minimize heat transfer by radiation or convection. The power through the calorimeter can be fitted to an equation of the form

$$P = [m_1 + m_2(T_{bath} - T_{ref})]V_{clmtr} + [b_1 + b_2(T_{bath} - T_{ref})]$$

where $V_{clmtr}$ is the output voltage of the calorimeter, $T_{bath}$ is the bath temperature, and $T_{ref}$ is an arbitrary reference temperature (we use 50°C); $m_1$, $m_2$, $b_1$, and $b_2$ are calibration parameters having typical values of 14.76 W/V, -0.0093 W/V°C, 0.00214 W, and 0.00046 W/°C when $T_{ref}$ is set at 50°C. This parameterization fits the calibration data to within a few tenths of a per cent or a few milliwatts, whichever is greater. The calorimeter output is essentially independent of the position of the heat source in the cell. A backup measurement, using the temperature difference between parts of the calorimeter inside and outside the thermoelectric units, has uncertainties of a few per cent or a few tens of milliwatts, whichever is greater; this part of the system provides redundancy to warn against any failures of the primary measurement. Data taken with both active and control cells will be presented.

## UTAH - Pd/D CALORIMETRY

Wilford N. Hansen (Phys. Dept., Utah St. Univ., Logan, Utah) and Michael E. Melich (Naval Postgrad. Sch., Monterey, California), "Pd/D Calorimetry -- the Key to the F/P Effect and a Challenge to Science," presented at ICCF4.

AUTHORS' ABSTRACT

By now Pd/D calorimetry has greatly advanced, both experimentally and in method of analysis. In fact, key data sets from the past, if carefully documented, can be reanalyzed with much enhanced insight. This is very important, especially for the experiments which have come to determine national and international policy. The main issue before this conference can be stated as a simple question: Question #1: Can large amounts of heat be generated at a significant rate by Pd/D interaction as announced by Fleischmann and Pons? The "large amounts" are much larger than can possibly be explained by chemistry or metallurgy as known today. Up to now the only practical way of answering this question is by Pd/D calorimetry. That being so, a second question naturally follows. Question #2: Are there any Pd/D calorimetric data sets extant which are competent to answer Question 1? There are indeed experiments which taken at face value do answer Question 1, with a resounding "yes." However, because of the extreme significance of such an answer and the apparent difficulty in nailing down all the parameters necessary to make the experiments repeatable, it may be reasonable to expect scientists to be highly skeptical and require unusually high standards of proof. Also, nature seems to have dealt us a case more profound and evasive than imagined at first. But this should not be blamed on F/P or other researchers. The challenge to science is to solve the case, with hard work and rational dialogue. The subject of what constitutes valid evidence will be addressed, and some approaches to data analysis will be given. Some Harwell and F/P data will be discussed. Some of our own attempts to answer Questions 1 and 2 will also be discussed.

## UTAH - STUDIES AT BYU

S.E. Jones (BYU/Los Alamos Nat. Lab. Collaboration, Dept. Phys. and Astro., Brigham Young University, Provo, Utah), "Piezonuclear Fusion Studies at BYU," presented at ICCF4.

AUTHOR'S ABSTRACT

A first paper exploring the notion of piezonuclear fusion was written in 1985. In particular, the idea of fusion in metallic deuterium (without muons) was considered. Two months after publication of this paper, an experimental program commenced at BYU to search for possible nuclear effects due to piezonuclear fusion in deuterium-charged metals as well as in geological processes. An underground laboratory facility designed for these studies has begun operation inside a mountain 10 km from the BYU campus, based on support from the U.S. Department of Energy and the Electric Power Research Institute. This facility is used to extend and scrutinize claims of low-level fusion in deuterided metals and is available to all responsible researchers.

Our primary detector for low-level neutron emissions consists of a central plastic scintillator 25 cm in length and 8.9 cm in diameter. A central cavity 4.4 cm diameter admits test cells. Fast neutrons from the sample can generate a recoil proton in the plastic generating scintillations which are viewed by a photomultiplier tube. Then the neutron slows further in polyethylene moderator 28 cm diameter X 30 cm long, and finally may be captured in one of 16 helium-3-filled proportional counter tubes embedded in the moderator. These tubes are arranged in four quadrants incorporating 4 proportional-counters in each.

Our detector/experiment has the following special features:

1. All signals are digitized using a LeCroy fast-waveform digitizer operating 100 MHz, so that we retain detailed pulse-shape information as well as timing between pulses. Pulseshape analysis permits excellent noise rejection, along with giving crude neutron-energy information (from the prompt plastic scintillator pulse). By studying time distributions from prompt and capture-neutron pulses, we check whether the spectra agree with distributions found with a plutonium source (see below).

2. The PC-based data acquisition system records in which of the four quadrants the neutron was captured, allowing for checking that the quadrants are hit in equal proportions. This segmentation has, for example, allowed us to throw out apparent large bursts of neutrons (over 60 in a 160 microsecond window) whose signals unrealistically came from just one or two quadrants.

3. Three large cosmic-ray veto counters show the passage of cosmic rays, which events are rejected off-line. Passive shielding of at least 80 m of rock also cuts down cosmic rayinduced events and removes dependence on atmospheric pressure. After cosmic-ray rejection, the event rate is approximately 0.7 neutron-like singles per hour with an efficiency of 15% for 2.5 MeV neutrons, and 0.07 burst-events per hour with a detection efficiency exceeding 20% (increasing with neutron-burst multiplicity).

4. We study for the first time differences between deuterium entering, leaving, and stable in thin Pd wires, which results in a set of controls in which deuterium is present, since we find (tentatively) that the outgassing case correlates most strongly with neutron-burst emission. (The correlation of low-level particle emission with deuterium outgassing was first reported by Ed Cecil of the Colorado School of Mines, and has since been found by others.) For completeness, we also use hydrogen-loaded metals for controls.

5. Two other sensitive neutron/gamma detectors are available in the same deep underground facility based on a different neutron-capture scheme (capture in lithium-doped glass), to permit checking of positive results found in the primary detector. The results are currently being checked in one of these independent detectors.

## UTAH - REPORT FROM MINSK

Hal Fox (Editor, *Fusion Facts*), "Summary of International Conference on Possibilities of Ecologically Clean Energy Production and Energy Conservation, Minsk, Belarus, May 25-27, 1993," *Fusion Technology*, 1993, vol 24, no 4, pp 431-433.

AUTHOR'S SUMMARY

The International Conference on Possibilities on Ecologically Clean Energy Production and Energy Conservation was co-hosted by the Environmental Program Centre for Citizen Initiatives, an American nonprofit agency that is working to help curtail the creation of unreliable nuclear power plants, and by the Belarussian newspaper, *NABAT* (which means alarm or bell in Russian). Belarus was heavily damaged by the radiation from the Chernobyl nuclear power plants to solve their 90% energy dependence on foreign energy sources. The people of Belarus do not want unsafe nuclear power. The purpose of the conference was to discuss energy alternatives. Cold fusion was such a major topic that a special session was devoted to it.

V.A. Filimonov (Inst. Physico-Chemical Problems) has recently received a small amount of funding for his proposed cold fusion research. He has excellent material science-type resources such as a scanning electron microscope to use. This funding will bring Belarus into the family of some 30 nations in which cold fusion research and development is being performed.

## UTAH - TRITIUM GENERATION

Fritz G. Will (Dept. Chem. & Fuel Eng., Univ. Utah, presently at EPRI), Krystyna Cedzynska (Inst. Gen. Food Chem., Tech. Univ. of Lodz, Poland), and Denton C. Linton (Dept. Phys., Univ. Utah), "Tritium Generation in Palladium Cathodes with High Deuterium Loading During Heavy Water Electrolysis," presented at ICCF4.

AUTHORS' ABSTRACT

Low-level tritium generation during $D_2O$ electrolysis with Pd cathodes was first reported by Fleischmann and Pons, followed by many others, but has proven sporadic and irreproducible. We have observed reproducible tritium generation up to 50 times background during $D_2O$ electrolysis in tightly closed $D_2SO_4$-containing cells in four out of four cases using Pd wire cathodes of one type. No tritium generation was observed in four identical Pd cathodes in $H_2SO_4$ cells, operated at the same time under the same conditions. Tritium analysis was performed before and after an experiment on Pd, electrolyte and gas in the head space. A cyclic loading/unloading regime with low current densities, rather than the usual continuous constant current regime, was employed to attain D/Pd and H/Pd loadings of 1 ± 0.05 on sixteen out of sixteen Pd electrodes of different origins. Continuous in-situ determination of the loading ratios was performed with a volumetric technique.

The largest amount of tritium, generated in 7 days of continuous electrolysis, was 2.1 x $10^{11}$ tritium atoms, as compared to a background of 4 x $10^9$ tritium atoms. Specific tritium yields for four 2 mm diameter Hoover & Strong Pd wire electrodes were in the range from 8.4 x $10^{10}$ to 2.1 x $10^{11}$ atoms/g Pd or 4.3 x $10^{10}$ to 1.1 x $10^{11}$ atoms/$cm^2$ Pd. This compares to a range of values from 2.5 x $10^{10}$ to 6 x $10^{12}$ atoms/$cm^2$ as determined by seven of ten other groups reporting tritium. Average tritium generation rates in the four heavy water cells were from 5 x $10^4$ to 2 x $10^5$ atoms/s/$cm^2$. This is equivalent to an average power level of the order of $10^{-7}$W, too small to be detected.

No tritium was found in four heavy water cells, employing Pd electrodes of another type or a Pd-Li alloy electrode, in spite of having attained D/Pd ratios of 1 ± 0.05. D/Pd loadings exceeding 0.8 ± 0.05 appear to be a necessary but not sufficient condition for tritium generation. Metallurgical factors also appear to be significant. The difficulty in attaining D/Pd loadings > 0.7 with continuous rather than cyclic loading methods, coupled with the as yet unknown effects of the Pd metallurgy, may account for the failure of many groups to observe measurable tritium generation.

A closed-system acid digestion technique, coupled with distillation and catalytic hydrogen oxidation and followed by liquid scintillation counting, was employed to determine the amount of tritium in the Pd. Beta ray spectra of the samples and of tritium standards were taken and established tritium as the source of the beta emission. Tritium was found in all four 2 mm Hoover & Strong Pd cathodes which had been used in $D_2SO_4/D_2O$ electrolysis. The average amounts ranged from 1.4 x $10^{10}$ to 4.4 x $10^{10}$ atoms/g Pd, compared to a maximum background of 5 x $10^8$ atoms/g. The axial distribution of the tritium was determined by cutting each Pd electrode into several pieces and analyzing them separately. A maximum concentration of 9 x $10^{10}$ atoms/g Pd or 180 times background was found. The ends of the electrodes had lower concentrations than the center regions. None of the four Pd electrodes used as blanks in $H_2SO_4/H_2O$ solutions showed any tritium within the detection limit of 5 x $10^8$ atoms/g.

The TID distribution over the three phases -- Pd, electrolyte and gas --is highly non-equilibrium. The T/D distribution factors --T/D in the Pd: T/D in the electrolyte or gas -- are in the range from 37 to 233. By contrast, typical equilibrium isotopic separation factors are between 0.2 and 0.4. This shows that the tritium was generated inside the Pd rather than at its surface and that several days were insufficient for the tritium to diffuse out of the Pd and equilibrate among the three phases.

To assess the probability that the tritium found in the four 2 mm Hoover & Strong Pd cathodes used in $D_2SO_4$ cells was due to chance contamination of the as-made Pd wire rather than to reactions occurring in the Pd during the experiments, large numbers of as-made Pd samples of different origins were also analyzed for tritium. Within the sensitivity of the analysis, i.e., 5 x $10^8$ atoms/g Pd, no tritium was found in any of 150 as-made Pd samples, comprised of wires from three different manufacturers, as well as several foils and powders. More than 100 Pd samples originated from Hoover & Strong. Thirteen control pieces were cut from the same spool of 2 mm Hoover & Strong Pd wire from which the four Pd cathodes were cut that had shown significant tritium after high D loading in $D_2SO_4$. None of the thirteen controls showed any tritium. The probability that the tritium in the four cathodes is due to chance contamination is 1 to 130,000 if the envisioned impurity distribution is assumed to be random. It is concluded that the tritium, which is found in the four tightly closed cells after several days of $D_2O$ electrolysis, was generated by nuclear reactions inside the highly D-loaded Pd electrodes.

## VIRGINIA - HYDROGEN-ION BAND STATES

Scott R. Chubb and Talbot A. Chubb (Research Systems, Inc., Arlington, VA), "The Role of Hydrogen Ion Band States in Cold Fusion," presented at ICCF4.

AUTHORS' ABSTRACT

Known phenomena involving hydrogen (H) and deuterium (D) diffusion inside and on the surfaces of transition metals provide evidence that both H and D may occupy wave-like band states (H or D ion band states) analogous to the electron band states that are responsible for making metals conductors. When these wave-like ion band states become occupied, fusion without emission of gamma rays involving D+D → $^4$He can occur. The quantum mechanics associated with this alternative form of fusion through ion band states is the basis of our Lattice Induced Nuclear Chemistry (LINC) theory of Cold Fusion.

LINC, which follows from known laws of solid state physics and quantum mechanics, replaces a number of assumptions that are universally accepted by nuclear physicists with more appropriate assumptions that are known to apply in a solid state physics environment. As a consequence, LINC also accounts for and is based upon a large number of observed effects involving H and D ion band state occupation in Pd, PdH, and PdD, that are not directly related to Cold Fusion. An important reason solid state physics effects can alter the possibilities for D-D fusion is that the factors limiting fusion in solids (and other bound systems), as opposed to those limiting D-D fusion in free space, are quantum mechanical particle-particle wave function correlations, which can inhibit

overlap. Whether or not these limiting effects occur is determined by system energy minimization, not Gamow theory.

We previously predicted that to minimize energy in PdD, 1) $D^+$ ion band states become occupied, 2) $D^+$-$D^+$ overlap occurs, and 3) then, nuclear reactions of the form D+D $\rightarrow {}^4He$ occur in which all participants occupy ion band states because $D^+$-$D^+$ overlap between ion band states is unstable with respect to ${}^4He^{++}$ formation provided (again to minimize system energy) the ${}^4He$ forms in an ion band state. In these reactions, the charge of each ion band state and the resulting overlap between the initial and final state ion band states are infinitesimally small in each unit cell but are distributed throughout the crystal. As a consequence, each reaction releases small (but equal) amounts of heat throughout the lattice. These distributed reactions occur provided a "distributed charge view of quantum mechanics" is correct, in which the charges and nuclear energy in a nuclear reaction become distributed over a finite volume.

LINC is a self-consistent quantum field theory: possible reactions are restricted by selection rules that are required by the theory in order to make the theory applicable. As a consequence of these rules, we predicted important effects that were subsequently observed. In particular, the combination of 1) over-charging a $PdD_x$ electrode so that values of x slightly exceed unity, 2) maintaining sufficient crystalline order, and 3) the known many-body effects that result when identical particles share a common wave function make cold fusion possible. Thus, in agreement with experiment, the theory has predicted that in $PdD_x$, for Cold Fusion to occur, it is required that A) x $\rightarrow$1, B) the predominant Cold Fusion by-products should be heat and low-energy ${}^4He$, and C) that the by-product ${}^4He$ should remain largely "untrapped" and be found in regions outside heat-producing electrodes.

To minimize the energy of the entire system, the energy in each reaction is distributed over many lattice sites, inhibiting production of energetic particles, except potentially when periodic order is suddenly reduced. LINC also implies, again in agreement with experiment, that steady state power will be proportional to loading current and might explain "normal" water anomalous heat production as a result of the heavy water present and the known electronic structure of Ni. LINC also implies that tritium might result from occupation of ion band states by both light and heavy hydrogen.

## C. NEWS FROM ABROAD

### CHINA - THERMONUCLEAR INTERCHANGE

Yi-Fang Chang, Chuan-Zan Yu (Dept. Phys., Yunnan Univ., Kunming), "Interchange of Thermonuclear and Cold Fusion," presented at ICCF4.

AUTHORS' ABSTRACT

The difficulties exist in thermonuclear fusion. We discuss a mechanism and some characters of the generalized fusion (including cold fusion), in which some methods can be applied to thermonuclear fusion.

Now some doubts about magnetically confirmed toroidal tokamak in nuclear fusion are discussed from an Ampère repulsive force. Cold fusion is having remarkable progress, although its physical mechanism is still unknown.

Based completely on the known quantum theory, we introduce the generalized nuclear fusion, this is a type of excess heat nuclear reaction in which the nuclear structures are changed by incident deuterons, etc. It includes various cold fusion effects. By using the penetration factor

$$d = \exp[-\frac{4\pi}{h}\int_a^b \sqrt{2m(U-E)}dr] \qquad (1)$$

of an any barrier in quantum mechanics, if U is the Coulomb potential $ke^2/r$, so

$$d \approx \exp\{-\frac{4\pi\sqrt{2m}}{h}[(\frac{ke^2}{r}-E)^{1/2}r - \frac{ke^2}{\sqrt{E}}arctg(\frac{ke^2}{rE}-1)^{1/2}]_a^b\} \qquad (2$$

where in (1) a=R is the distance of strong interaction between both incident nucleus and target, $b=r_0=ke^2/E$. Then

$$d \approx \{-\frac{2\pi\sqrt{2m}}{h}[\frac{ke^2}{\sqrt{E}}arctg(\frac{ke^2}{RE}-1)^{1/2}R]\} \qquad (3)$$

For $D=Pd^{106}$, because m=l876.0289 Mev/$c^2$, R=l.25$A^{1/3}$=5.9158 fm, k=z=46, if E=240KeV, so d=9.64827 x $lO^{-52}$. It is too small, the above cold fusion becomes a puzzling problem. Therefore, we propose the multistage nuclear reaction mechanism of the generalized fusion:

1. When E=240Kev, the nuclear reaction is
D + D $\rightarrow$ $He^3$ (0.8175MeV) + n (2.4527MeV)
D + D $\rightarrow$ T (1.01MeV) + P(3.03MeV) (4)

where R=l.25x$2^{1/3}$ = 1.5749fm, k=z=l, so d=0.33893 by the formula (3).

2. The nuclear reaction
P(3.03MeV) + $Pd^{106}$ $\rightarrow$ $Ag^{107}$ (5)

appears, d=6.2467334x$l0^{-5}$. This is possible too. The other reactions correspond to the smaller d, for example, d=5.054055x$lO^{-22}$ for T(1.01MeV) + .$Pd^{106}$ $\rightarrow$ $Ag^{109*}$.

3. A neutron in (4) can produce many nuclear reactions, and various nuclear reactions may be represented briefly

$$\begin{bmatrix} P \\ n \\ D \\ . \\ . \\ . \end{bmatrix} + \begin{bmatrix} D \\ Pd^A \\ T \\ He^3 \\ . \\ . \\ . \end{bmatrix} \rightarrow \begin{bmatrix} He^3 & Ag^{A+1} & He^4 & Li^{4*} & \cdots \\ T & Pd^{A+1} & H^{4*} & He^4 & \cdots \\ He^4 & Ag^{A+2} & He^{5*} & Li^{5*} & \cdots \\ . & . & . & . & \end{bmatrix} \qquad (6)$$

where some compound nuclei are unstable.

When the nuclear reaction may be performed, we predict that the following conditions are favorable to nuclear reactions and the generalized fusion:
1. Increase energy of incident particles, for example, speed of particles or electric field is increased.
2. Choose nucleus whose barrier is lower or thinner.
3. Choose an incident particle whose mass is smaller, in which the smallest proton has an electric repulsion with nucleus, while neutron is unstable and doesn't act for electromagnetic field; while deuteron may move in an electric field, and possesses the Oppenheimer-Phillips effect,

$$D + A \rightarrow P + (n+A)$$
$$D + A \rightarrow n + (P+A) \quad (7)$$

which is favorable for many reaction modes.
4. Increase the flux density of incident particles, the target nucleus number or the total area of reaction, so the geometrical cross section of electrolytic cathode is an important factor.
5. Accumulate reaction time continuously under the same conditions. According to the quantitative calculations of the multistage nuclear reaction theory, we think that H-3 and neutrons, T and protons, will appear together in the same experiments, perhaps, part of these particles reacts quickly with other nuclei. Since the premise of this fusion is accumulation of deuteron, so those materials whose adsorption ability is stronger for deuteron, for example, Pd, or whose surface has much holes are better.

Based on the experiments in which antiproton can form the metastable states, we have proposed a new idea of nuclear fusion for the ignition by the antiproton beam.

In fact, the original nuclear fusion has two controlled methods: thermonuclear fusion and acceleration. For the latter the incident nuclei collide with sufficient energy to overcome the electrostatic repulsion force between nuclei. It requires that all incident nuclei move in the same direction. But one believes usually that this way isn't applicable. In the cold fusion, Pd adsorbed much deuterons to form the D-target, the incident particles move in the same direction under the reaction of electric field, the reaction time is accumulated continuously, so excess heat can be produced.

Further, we can apply some methods of the cold fusion to the controlled thermonuclear fusion. For example, if Pd, etc., whose adsorption ability is very strong for deuteron, are made to become a very small powder, as $10^{-6}$~$10^{-9}$m size, then pour into in a container of the thermonuclear fusion. These powders, as the core of adsorbed deuterons, will help to reach the ignition conditions. Reversely, the some ideas and technologies of thermonuclear fusion may be applied in cold fusion. In a word, an interchange of thermonuclear and cold fusion will be helpful to each other.

## CHINA - HV PULSE DISCHARGE

Jiangtang He, (Inst. of High Energy Phys., Academia Sinica, Beijing), "A Study on Anomalous Nuclear Fusion Reaction by Using HV Pulse Discharge," presented at ICCF4.

AUTHOR'S ABSTRACT

A study on anomalous nuclear fusion reaction by using 10 kV pulsed high voltage discharge in deuterium was completed. During HV pulses no neutron signal was detected, but two peaks of gamma rays were detected. The energies of two gamma rays are at 425 keV and 870 keV respectively. It might be explained as $^{108}Pd^*$ and $^{56}Fe^*$ excited by high energy charged particles de-exciting radiations. Neither neutron signal nor gamma signal was detected in the intervals between the pulses.

## CHINA - HIGH TEMP. SUPERCONDUCTOR IN C.F.

Shang-xian Jin, Fu-xiang Zhan and Yu-zhen Liu (Grad. Sch., Univ. Sci. & Tech. of China, Beijing), "Deuterium Absorbability and Anomalous Nuclear Effect of YBCO High Temperature Super-Conductor," presented at ICCF4.

AUTHORS' ABSTRACT

The experimental studies of YBCO-D system indicated that YBCO high temperature super-conductor (HTSC) was shown to have a similar effect on deuterium absorbability and anomalous nuclear effect like palladium. We found that $Y_1Ba_2Cu_3O_{7-\delta}$ could absorb deuterium at normal temperature and forms $D_xY_1Ba_2Cu_3O_{7-\delta}$. We also found that the deuterated YBCO could produce high energy charged particles far larger than background. The influence of the absorbed deuterium on the characteristics of YBCO HTSC and the mechanism of the anomalous nuclear effect are not clear and needed to be further studied.

In this experiment the YBCO HTSC sample was prepared by a new technology that high speed, direct combination of $Y_2O_3$, $Ba_2$ and CuO which were made up on 1, 2 and 3 weight. The zero resistance temperature of the sample was 90°K. The $Y_1Ba_2Cu_3O_{7-\delta}$ pellet or powder was put on the frame in the vacuum chamber. The CR-39 nuclear track etch detectors, which are used to detect charged particles, were placed around the sample. The chamber was evacuated to about $10^{-3}$ torr and then filled with 99.8% purity deuterium of ~1 atm. About 1 or 2 days later, the CR-39s were taken out and etched and observed in the microscope.

The specific property of deuterium absorption by the YBCO HTSC in the normal temperature is shown. The content ratio of deuterium in $D_2Y_1Ba_2Cu_3O_{7-\delta}$ was about x~ 0.2. A photo was taken of nuclear tracks on the CR-39. The net number density of the tracks after subtracting the background was ~ $3x10^5$/cm2. The statistical distribution of the tracks with circular surface pattern on the CR-39, which were produced by the vertically incident particles, is shown. For comparison, the statistical distribution of the tracks with circular surface pattern on the CR-39, which were produced by the vertically incident $\alpha$-particles from standard $^{241}Am$ $\alpha$-source is shown. Comparing two figures with the paper, we can see that the deuterated YBCO HTSC could produce high energy charged particles of several kinds or/and with different energies. The control experiments were performed without filling deuterium and no anomalous effects were found. Further study is needed for identifying the particles and measuring the energy distribution.

The YBCO high temperature super-conductor can absorb deuterium at normal temperature and forms $D_2Y_1Ba_2Cu_3O_{7-\delta}$. The deuterated YBCO HTSC could produce high energy charged particles far larger than background. The mechanism of the anomalous nuclear effects and the influence of absorbed deuterium on the characteristics of YBCO HTSC are not clear and needed to be further investigated.

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**CHINA - RESONANCE TUNNELING**

Xing Zhong Li (Dept. Phys., Tsinghua Univ., Beijing), "The 3-Dimensional Resonance Tunneling in Chemically Assisted Nuclear Fission and Fusion Reactions," presented at ICCF4.

AUTHOR'S ABSTRACT

"Excess heat" has been confirmed by the experimental data from SRI (McKubre) and Nice (Fleischmann & Pons). The amount of total excess heat excludes the possibility of being usual chemical reaction heat, the possible candidate is the heat of nuclear reaction. However, nuclear physicists do not accept this inference with ease, because they do not see the corresponding nuclear products.

The deuteron-deuteron fusion reaction was the first candidate, since the deuterium was involved at the beginning, and the deuteron has the lowest Coulomb barrier. Gradually, some are reluctant to accept d-d fusion reaction as the origin of excess heat, because the neutron yield is much lower than that expected in d-d reactions. The anomalous branch ratio was suggested to explain the missing neutrons, and the tritium production was measured instead. This suggestion could not save the d-d fusion reaction, because we did not see any reliable report about the 14 MeV neutron emission. In an excess heat experiment, usually, several watts of "excess heat" were produced, this should correspond to more than $10^{12}$ d-d fusion reaction per second; hence, $10^{12}$ tritons were produced every second. In a deuterium rich environment (heavy water and deuterated palladium) we should expect at least one 14 MeV neutron from every $10^5$ tritons (with 1.01 MeV as initial triton energy). However, this is not confirmed by experiment up to now.

Nuclear fission reaction was the second candidate. When the number of nuclei is greater than 100 (A>100), fission is always possible according to the energy balance (for example $^{102}_{46}P$ may produce $^{30}_{14}Si + ^{72}_{32}Ge$ + 9.583 MeV), and silicon has been observed on the surface of the palladium in the experiments. The first question is still the penetration of the fission barrier. The fission is preceded by the deformation of nucleus, which needs an activation energy of 5 MeV ~ 20 MeV. However we do not have the energy source for this activation in deuterium/solid systems. The second question is: where is the nuclear radiation. Usually, the fragments of nuclear fission are highly radioactive. At least we should expect a lot of $\gamma$ radiation. Our model attempts to solve these two questions.

The first question about penetration may be answered by the 3-dimensional resonance tunneling of double-barrier, which was proposed (by Li) to assume the low energy d-d reaction. In fact, this mechanism works as well for the fission reaction if we consider the high density electrons surrounding the nuclei. We may call it chemically assisted nuclear reaction or double-barrier fission, because the electrons help to form double barriers, the fission barrier, and the centrifugal barrier. The double barrier fission was proposed early in 1980's (Bjørnholm et al.) to successfully explain the fission of the isomer of nuclei. A large deformation of nucleus was assumed there to form the double barriers. However, we are proposing the centrifugal barrier to be the second barrier in addition to the first fission barrier. The high density electrons are supposed to dig a well between the first fission barrier and the second centrifugal barrier. As a qualitative illustration, the Thomas-Fermi model for electron gas is assumed. The interchange energy of electrons are included by Hitler-London method. The critical electron density is related to the deuterium loading ratio of palladium (D/Pd), and the probability of penetration is estimated. They are compared with experimental data.

The second question about the missing radiation due to fragments can be answered by this double barrier fission model also. Because the fragments are dwelling in the potential well formed by high density electrons, the strong interaction between fragments and surrounding electrons enhances the internal conversion mechanism, and the excitation energy of fragment prefers to be transferred to electrons rather than to the emission of $\gamma$ radiation. We should expect a lot of $\beta$ radiation in stead of $\gamma$ radiation. An experiment is designed to verify this prediction. Based on this double-barrier fission model , the enhancement of deuterium loading ratio is just to provide high enough electron density in the palladium; then, what is the mechanism to cause the big difference between hydrogen and deuterium in experiment? The deuteron (with spin 1) is a boson, and proton (with spin 1/2) is a fermion. The Bose-Einstein condensation may happen in palladium for deuterons. A macroscopic amount of deuterons may be condensed into a same energy level, this may introduce the double-barrier penetration and cause the d+Pd reaction. Once deuteron penetrates into the palladium nucleus, much more nuclear reaction channels would be open, including more double barrier fission channels of the compound nucleus. Therefore, more energy would be released in deuterated palladium in comparison with the light water electrolysis experiment.

The Bose-Einstein condensation must be accompanied by the high local electron density, and the high local pressure. The strain allowed inside the palladium would limit this maximum possible pressure. A theoretical calculation is done to estimate this maximum pressure, and an experiment based on positron-electron annihilation is designed to detect these regions of high local electron density. The empirical rule found by Storms and Fleischmann & Pons seems compatible with this model. In fact, the cracks on the surface of palladium electrode, or the volume expansion after the absorption of deuterium gas may stop the formation of the high local electron density region.

As a summary, double barrier resonance tunneling is proposed as a mechanism for both the penetration of deuteron into the palladium, and the fission of palladium (or compound nucleus of palladium + deuteron). The key issue is to search the $\beta$ radiation and the high density region of electron.

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## CHINA - X-RAY ANOMALY

He-Qin Long, Wen Yin (Inst. of Sichuan Mat. & Tech.), Xin-Wei Zhang, Jun Wu, Wu-Shou Zhang (Inst. Appl. Phys. and Computational Math., Beijing), Hong-Qing Tang, Ze Li, Quan-Ren Shen, Zu-Ying Zhou, Bu-Jia Qi, Yong-Hui Liu, Xiao-Zhong Wang, Yi Yang (Ch. Inst. of Atomic Energy, Beijing), "New Experimental Results of Anomalous Nuclear Effect in Deuterium/Metal Systems," presented at ICCF-4.

AUTHORS' ABSTRACT

Counts and energy spectrum of anomalous neutron and probable anomalous X-rays have been detected in Deuterium / Metal gas discharge Systems. Electrodes were made of Pt, Nb, Ta, WThx, W.Pd, Cu, Mo, Ag, Fe or other metals and were fixed at both ends of a glass reaction bulb, the effective value of applied alternating voltage was 2.7-18KV (50Hz). 2.45 Mev neutrons have been measured on condition of dynamic low pressure (<100Pa) deuterium gas glow discharge, neutrons of other energy over background have not been detected. The ratio of experimental neutron yield to theoretical yield was more than 1 when low voltage was applied. The ratio >8 in WThx system when U=4.7KV; the ratio >46 in Ta-D system when U=4.1KV; the ratio >170 in Nb-D system when U=2.7KV. The neutron emission was stable, reproducible and controlled.

Comparing with air discharge, there were indications that anomalous X-ray had been produced in the Pd-D system. The X-ray spectrum ($E_x$<20KeV) detected was similar to the bremsstrahlung spectrum but not any normal spectrum of which low energy X-ray was absorbed mostly by the glass wall of reaction bulb (~2mm thick).

## CHINA - PRESSURIZED CELL

Da Wei Mo, Yi Si Lu, Li Ye Zhou, Zing Zhong Li (Tsinghua Univ., Beijing), "Investigation on the Excess Heat in D/Pd System Using Pressurized Electrochemical Cell," presented at ICCF4.

AUTHORS' ABSTRACT

Most of excess heat experiment was done in electrolysis cell. The temperature was less than 100°C. The pressure was no more than 1 atm. The cell was made of glass. It is complicated to analysis the experiment data for this condition.

Several experiments have developed from it. This experiment plans to undertake building a cell, which can work at more than 100°C and more than 1 atm., and the expense of heavy water is small. If the excess heat is large enough, the experiment data can be understood easily and directly.

The calibration experiment has progressed. The excess heat experiment is planned to be done this year in Sept. and Oct. Safety and protection have been considered. A catalyst and relief valve are used in our cell.

## CHINA - NEUTRON BURST MEASUREMENTS

Xiaozhong Wang, Rongbao Zhu, Peijia Tang, Wenliang Zhang, Hengjun Liu, Feng Lu, Guoan Chen, Jagun Liu, and Zhonglin Chen (China Inst. Atomic Energy, Beijing), "A New Device for Measuring Neutron Burst in Cold Fusion Experiment," presented at ICCF4.

AUTHORS' ABSTRACT

A new neutron detection system for observing deuterium behavior in metal (Ti) has been set up and used in measuring neutron bursts from temperature cycling of metal (Ti)-deuterium systems. The equipment is composed by HLNCC-II device with 18 $^3$He thermal neutron counters and an AST-386 computer with time distribution retrieval model. The computer can retrieve all time labeled pulses of $^3$He counters within time interval of 128 μs to examine the decay behavior of neutron bursts for the purpose of distinguishing the neutron signals from electronic noises.

The experiment is performed to measure electronic from spikes occurring in high voltage junction box during forced cooling down period of HLNCC-II. The decay time derived from time distribution of neutron counts in two neutron bursts generating in temperature cycling of metal (Ti)-deuterium system is 52 μs, which is consistent with the 46 μs for $^{252}$Cf source declared by HLNCC-II developer. Such a consistency prompts the probability of anomalous production of nuclear reaction in the system.

## CHINA - COLD FUSION AND NEW PHYSICS

Jie Fu Yang, Xiao Mei Chen and Li Jun Tang (Dept. Phys., Hunan Normal Univ., Changsha, Hunan Province), "Cold Fusion and New Physics," presented at ICCF4.

AUTHORS' ABSTRACT

Some problems revealed by cold fusion are the frontier-problems of science and newly discovered physics. It is meaningless to try to understand and appraise these new results by the traditional ideas.

1. "Abnormal" Nuclear Phenomena Discovered as New Nuclear Process: The traditional fusion idea is the fusion between a nucleus and a nucleus, for example deuteron-deuteron fusion or triton-triton nuclear fusion. This fusion has the obstacle of traditional Coulomb barrier. In ordinary temperature and low voltage condition, the nucleus-nucleus fusion is impossible from the energy requested. It may be a main reason for some people to oppose cold fusion.

However, cold fusion has already occurred in many laboratories; lately, the experimental results of several laboratories in China show that the repetitive ratio of the "abnormal" nuclear phenomena can reach 100%, the neutron yield is above $10^4$/s, and it can be repeated at any time by using full deuterium-glow discharge method, except the electrode loses efficacy. In addition, the "excess heat" experiment of Fleischmann and Pons obtains progress too.

There is a new fusion under ordinary temperature condition that is possible if the fusion occurs between a neutral particle and a nucleus, but it requires a new physics process to produce the new neutral particle, that is a nuclear process to remove the Coulomb barrier before the fusion.

2. Weak Interaction Process: (1) A Possible Process to Produce Neutral Particle: After analyzing the cold fusion experiment and interactions in natural world, we think the way to produce neutral particle may be weak interaction process. For example, an excited deuteron captures an electron and produces a neutral particle at the same time. The process is

$$ {}^{2}_{1}H^{*} + e \rightarrow {}^{2}_{0}N^{*} + \nu_e \qquad {}^{2}_{0}N^{*} \rightarrow {}^{2}_{1}N + \gamma \qquad (1) $$

where ${}_0^2N$ is dineutron. There is no obstacle of Coulomb barrier when a dineutron reacts with other nuclei, the fusion reaction can be produced at any temperature.

(2) Force Field of Producing Dineutron: Jie Fu Yang finds: the existence of weak interaction has its universality in nucleus; and that nuclear force contains part weak interaction force. There is nuclear force between proton and neutron in a deuteron, which contains weak interaction force too.

3. Estimation of Dineutron Mass

a) If we look triton as the constitution from a deuteron and a neutron, the binding energy is

$$ \left[ M({}^{2}_{1}H) + m_n - M({}^{3}_{1}H) \right] C^2 = \Delta m_1 C^2 \qquad (2) $$

we can consider triton as the constitution of a dineutron and a proton, too, and similarly write out:

$$ \left[ M({}^{2}_{0}N) + m_p - M({}^{3}_{1}H) \right] C^2 = \Delta m_1 C^2 \qquad (3) $$

$$ M({}^{2}_{0}N) = 2.0149u \qquad when \quad \Delta m_1 = \Delta m_2 \qquad (4) $$

b) there is reaction in dineutron mode the reaction energy

$$ Q = (M({}^{2}_{1}H) + M({}^{2}_{0}N) - m_n)\, C^2 > 0 \qquad (5) $$

$$ \therefore M({}^{2}_{0}N) > M({}^{3}_{1}H) + m_n - M({}^{2}_{1}H) = 2.01613u \qquad (6) $$

The dineutron mass can be determined by measurement of fusion neutron spectrum. For example:

$$ E_n < 3MeV, \qquad \therefore M({}^{2}_{0}N) < 2.0149u \qquad (7) $$

To contrast equations (6) and (7) then

$$ 2.010613u. < M({}^{2}_{0}N) < 2.0149u \qquad (8) $$

## CHINA - D-Pd NUCLEAR REACTIONS

Yu Chuan-Zan, Chang Yi-Fang, Wang Hul-Lan (Dept. Phys., Yunnan Univ., Kunming, PRC), "D-Pd System Nuclear Reactions and Fission Under Ambient Conditions," presented at ICCF4.

AUTHORS' ABSTRACT

Since the amazing announcement of Fleischmann and Pons on cold fusion was reported, many experiments attempted to reproduce this result. A lot of electrolysis experiments used Pd cathode in heavy water. Karabut et al. and Long et al. measured neutron and excess heat in D-Pd system at gas glow discharge chamber. It was reported by Iida et al. that cold fusion is induced in the vicinity of rear interface between Pd and MOS Layers.

The purpose of this paper is to present a more detailed numerical computation in justification of our theoretical model of nuclear reactions of D-Pd system. Our model has been analyzed completely, and compared to experimental results.

Theory: According to the quantum mechanics, the tunneling effect exists in microscope region. In our theory of nuclear reaction at room temperature, the production rate r is

$$ r = N_d N_x \sum_{i,j}^{n,m} \sigma_i d_i b_j v_j \qquad (1) $$

In this paper, the deuterium is the bullet nucleus, and the number density is $N_d$, the target nucleus have two: one is D adsorbed by Pd, D - D fusion reactions are D(D, n) $He^3$ and D(D, P)$T^3$, it is possessed of characteristic of 2.45 Mev neutrons or 3 Mev protons; another target nucleus is Pd, and the number density is $N_x$. It should be noted that Pd have six stable isotopes: $Pd^{102}$(0.8%), $Pd^{104}$(9.3%), $Pd^{105}$(22.6%), $Pd^{106}$(27.2%), $Pd^{108}$(26.8%), $Pd^{110}$(13.5%), abundance percent in parentheses. Calculated results that the D - Pd compound nucleus dual- fission released energy was simulated in an equation as follows:

*E(Mev) = a(A - Z)(A + 2 - 2l)/Z + b* (2)

where a = 0.2835, b ~ 0, 1 = 0, 1, 2, ...., A and Z are the target nucleus mass and charge number, respectively. If the fission is caused by neutron then the a=0.2450, the symmetric fission released energy bigger than 10 times the $\alpha$-decay energy. Karabut et al. reported that from energy spectrum of gamma-radiation at the Pd cathode, most of the Rh isotopes and some strange isotopes, such as $Sr^{86m}$, $Sr^{85m}$ etc. can be seen. We take $Rh^{104}$, $Rh^{105}$, $Pd^{109}$ for nuclear reactions, such as, $Pd^{106}$(D,d)$RH^{104}$, $Pd^{106}$(D,$He^3$)$Rh^{105}$, $Pd^{110}$(D,T) $Pd^{109}$ etc. In particular, $Sr^{86m}$, $Sr^{85m}$, etc. must be Pd fission products.

Takahashi et al. analyzed a "worn-out" Pd cathode material, and discovered tracer elements of Al and Si in it. We speculate that they can be produced by Pd fission products and released (18 - 21) Mev

energy. The D - Pd system gave experimental neutron spectra with the two components of 2.45 Mev and 3-7 Mev. The neutron energy, which we obtained from calculation of the nuclear reactions released energy of Pd six stable isotopes with D, is just 3 - 7 Mev.

Excess heat: Karabut et al. indicated that the best results of 78 calorimetric experiments is a 33W excess power at a 500% efficiency j, where $j = (Q_m - Q_{el})/Q_{el}$. $Q_m$ and $Q_{el}$ are the heat measured and electric discharge heat, respectively. Then excess power $W_m$ = 33W comes from compound nuclear fission. The yields is Y in time t = 40s and average energy release E = 30 Mev in every fission, i.e.

$$W_m = YEt \quad (3)$$

$$Y = W_m/Et = 1.7 \times 10^{11} s^{-1} \quad (4)$$

If the excess power produced by nuclear reactions, then the Y must be bigger than $10^{12}s^{-1}$. It is perhaps both mixed in reality. Karabut pointed out that without special means, the average values for excess heat time and the efficiency are 20 min. and 50%. Takahashi et al. obtained excess heat and the average values and efficiency are 70%. Both reported that the Pd cathode was etched after the work: one found a lot of small size "bubbles", and another appears as the "surface film boiling" in electrolyte. Most of the excess heat is released at the cathode, sometimes more than 90% of the total amount of heat, has been measured by calorimeter. We take evidence for nuclear reactions and fission. The Pd fission products, even with a high energy, will have small path and do not leave the cathode.

Reproducibility: We proposed that the theory of nuclear reactions under ambient conditions, could expect a number of reaction channels and decay channels from eq. (1), and may explain excess heat phenomena and the various experimental results which are different each other, then they appear probable and difficult to repeat.

From eq. (1), entrance channels i is from 1 to 7, $\sigma_j$ is cross section of nuclear reaction, obtained from the nuclear data table. The transmission barrier factor $d_i \sim 10^{-11} - 10^{-12}$ has been estimated by us through experiments. When the tunneling deuterons enter Pd nucleus, they become compound nuclear Ag, and have a lot of decay channels j>>7, due to the fact that each decay process is a function of the mass and charge distributions. Since the incident mode and decay mode have diversity and stochasticity, the same experiments have shown different results under the case of an insufficient sample point. This is nowadays a key problem that the mechanism of cold fusion has been unclear.

Conclusion: The nuclear reactions and fission under ambient conditions may be performed via the quantum tunneling effect at room temperature, through electric induction and coulomb barriers screening, the rate of tunneling is tremendously increased. We find strong evidence about nuclear reactions and fission from experimental results.

By mean of our theory that the incident channels and decay channels have multiplicity and stochasticity, the same experimental results have shown different from each other and difficult to repeat, in the case of an insufficient sample size. The final consistency must be with the help of a number of statistical averages from many experiments.

## CHINA - NUCLEAR REACTIONS

Chuan-Zan Yu, Yi-Fang Chang (Dept. Phys., Yunnan Univ., Kunmig), "Nuclear Reaction Under Ambient Conditions," presented at ICCF4.

AUTHORS' ABSTRACTS

Because the mechanism of cold fusion has been unclear for a long time, it is difficult to explain many phenomena, sometimes experiments are difficult to repeat. A number of experiments which we regard as cold fusion, in fact were nuclear reactions and nuclear fission at room temperature, only a few of those reactions belong to cold fusion.

In this paper, we discussed:
(1). Bush (l992) and Srinivasan et al. (1992) measured excess heat with solution of alkali carbonates. The authors agree with other researchers who have experimented with such light water cells using nickel cathodes, that this type of cell are much less "frustrating" to deal with than Pd-$D_2O$ cells. Also the excess heat results are more reproducible and success rate higher.
We speculate that the source of excess heat in alkali carbonates aqueous solution could perhaps be nuclear reaction of these types:

$P + Li^6 \rightarrow He^3 + He^4 + 3.95$ Mev;
$P + Li^7 \rightarrow 2He^4 + 12.4$ Mev;
$P + Na^{23} \rightarrow Mg^{24} + 11.7$ Mev;
$P + K^{39} \rightarrow Ca^{40} + 8.3$ Mev;
$P + K^{41} \rightarrow Ca^{42} + 10.3$ Mev;
$P + Rb^{86} \rightarrow Sr^{87} + 9.6$ Mev;
$P + Rb^{87} \rightarrow Sr^{88} + 10.6$ Mev;
$P + Cs^{133} \rightarrow Ba^{134} + 8.0$ Mev.

As mentioned above, it was nuclear reactions under ambient conditions exactly but not cold fusion. The source of excess heat produced in aqueous solution can be obtained by passable experimental measurements.

(2). While the maximum amount of tritium generated has been in a $K_2CO_3$ in 25% $D_2O$ cell (3390 Bq/ml), the second highest (2454 Bq/ml) was with a $Li_2CO_3$ in $H_2O$ cell by Srinivasan. They said that no "magic formula" has emerged for generating high levels of tritium so far. We proposed generation tritium nuclear reaction as follows:
$D + O^{17} \rightarrow O^{16} + T^3 + 2.13$ Mev;
$D + C^{13} \rightarrow C^{12} + T^3 + 1.32$ Mev
for $K_2CO_3$ in 25% $D_2O$, the stable isotope $O^{17}$ takes hold of 0.06% of oxygen, and the stable isotope $C^{13}$ takes hold of 1.11% of carbon element in aqueous solutions carbonates. Because natural water contains 1/6500 deuterium, the the above reaction for $Li_2CO_3$ in $H_2O$ still generated tritium production.

(3). Karabut et al., reported that from energy spectrum of gamma radiation at the Pd cathode, most of the rhodium isotopes and some strange isotopes, such as $Sr^{86m}$, $Sr^{85m}$ etc. can be seen.

We take $Rh^{104}$, $Rh^{105}$, $Pd^{109}$ for nuclear reactions, such as $Pd^{106}(D,\alpha)Rh^{104}$, $Pd^{106}(D,He^3)$ $Rh^{105}$, $Pd^{110}(D,T)Pd^{109}$, etc. In particular, $Sr^{86m}$,$Sr^{85m}$ etc. must be palladium fission products.

(4). The gas glow discharge in deuterium experiments were performed by Long et al., in which the cathode material has been Nb, Pt, W, Pd, Ag, Au, Mo, Fe, etc., then the non-fusion neutron was obtained, while the neutron energy of the D-D thermonuclear fusion must be 2.45 Mev.

We write these reaction equations as follows:
$Nb^{93}(D,n)Mo^{94}$; $Pt^{196}(D,n)Au^{197}$; $Ag^{107}(D,n)Cd^{108}$; $Au^{197}(D,n)Hg^{198}$; $W^{184}(D,n)Re^{185}$; $Cu^{63}(D,n)Zn^{64}$; $Mo^{98}(D,n)Tc$; Fe(D,n)Co; Pd(D,n)Ag, ......

The calculated neutron emission spectra having 3-7 Mev have been obtained by experimental measurement. (This neutron energy spectrum has been under suspicion due to the recent experiments in China, unfortunately).

(5) Takahashi et al. analyzed a "worn-out" Pd cathode material, inside tracer elements of Al and Si were discovered. We speculate that they can be produced by Pd fission products. The reactions are as follows:

$D+Pd^{106} \rightarrow Ag^{108*} \rightarrow Al^{27}+Se^{81}+18$ Mev;
$D+Pd^{108} \rightarrow Ag^{110*} \rightarrow Al^{27}+Se^{83}+18$ Mev.
$D+Pd^{106} \rightarrow Ag^{108*} \rightarrow Si^{28}+As^{80}+21$ Mev;
$D+Pd^{108} \rightarrow Ag^{110*} \rightarrow Si^{30}+As^{80}+21$ Mev.

In the nuclear reaction theory at room temperature presented by us, the reaction rate r is:

$$r = N_a N_x \sum_{i,j}^{n,m} \sigma_i d_i b_j b_j \qquad (1)$$

where $N_a$, $N_x$ is the number density, of bullet and target nucleus, respectively, enhance channels i from 1 to n, $\sigma_i$ is nuclear reaction cross section obtained from experiments. When the compound nucleus have a lot of decay channels j, each decay channels' branching ratio $b_j$ and decay velocity $v_j$ as parameter, are determined by experiments.

The theory of nuclear reactions at room temperature, we proposed, could expect about 10 reaction channels and decay channels by eq. (1), and may explain excess heat phenomena and the various experimental results, which are different from each other, then they have low probability and are difficult to repeat.

Another mysterious experiment was the "surface film boiling", of electrolyte at the end of 2 months run. Analogous work was reported by Karabut et al.: The Pd cathode after the work in the discharge chamber was etched and analyzed with a high resolution transmitting electron microscope. They find a lot of small size "bubbles." Most of the excess heat is released at the cathode, sometimes more than 90% of the total amount have been measured by calorimeter. As I mentioned above, we take evidence for nuclear reaction and fission products, Karabut and Takahashi already pointed out that the order of excess heat observed is about $10^3$ times greater than chemical heat sources, and charged particles with a good portion of alphas are found in quantities 3-4 orders short of those needed to explain the excess heat. We suggest that the energy of Pd fission products with large energy release is the source of most of excess heat energy which is obtained from experiments.

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## CHINA - CALORIMETRY

Zhongliang Zhang, Xuezhong Sun, Minggui Wang, Baozhen Yan and Fu Tan (Inst. Chem., Academia Sinica, Beijing), "Calorimetric Measurements of the Electrolysis of Heavy Water at Palladium Cathodes," presented at ICCF4.

AUTHORS' ABSTRACT

Results of calorimetric study of the electrolysis of heavy water at palladium cathodes are presented here. A Calvet type microcalorimeter, which is a kind of instrument used to determine the flow of heat (thermal power) evolved or absorbed in a process undergoing in a system, was employed in the work. The calorimeter was calibrated with Joule heating in power from 1 mW to 30 mW. The power input into the calorimetric system is a simple linear relationship with the calorimetric signal in voltage. The correlation coefficient of the relationship is 0.999. The results of the calibration with an electrical power in 10.94 ± 0.00 mW show that the measurements reproducibility is of the order of less than 1%. The electrolysis was performed in different conditions of current densities from 0.5 $mA/cm^{-2}$ to 6 $mA/cm^{-2}$ (of course, in different voltages concerned).

Two types of "excess heat" production during the electrolysis could be found in the present work if the electrolysis condition may be in a suitable state. One of them is called the "excess heat", which was found first by M.Fleischmann and S.Pons. The levels of the excess heat (or excess enthalpy) generation may be a few times over electrical power input into the system. One may believe that it depends on current density of electrolysis as reported by M. Fleischmann and S. Pons. But, in the present work, it was found that the excess heat is concerned in the cell voltage of electrolysis. Another is in a burst type generation, which can be observed in the time of decreasing the voltage of electrolysis. That was called by us to be "anomalous heat" generated during the electrolysis of heavy water. The heat generated seems to be independent of the current density, but it is dependent of the loading ratio D/Pd and may be observed over a suitable period of the electrolysis (at least 240 hrs. in this work). The levels of the anomalous heat generation are here over 10 per cent of the electrical power input into the system. In this work, it was found that the excess heat production had been observed much easily than the anomalous heat during the electrolysis of heavy water. The heat burst generated had been observed 9 times during the period of one long-term (about 300 hrs.) experiment, and for 15 times during another (about 600 hrs.), except every night-time of these runs. The final "over-all" standard deviation, as mentioned by F.D. Rossini, of these measurements could be estimated as less than ±5% only because of the obtained results caused by many uncertain factors, such as the changes of room temperature, etc. in this work.

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## CHINA - TITANIUM EXCESS HEAT

Q.F. Zhang, Q.Q. Gou, Z.H. Zhu, J.M. Lou, F.S. Liu, J.X.S.B.Y. Miao, A.P. Ye, S.M. Cheng (Inst. of Atomic and Molec. Sci., Chengdu Univ. of Sci. and Tech., Chengdu), "The Excess Heat Experiments on Cold Fusion in Titanium Lattice," presented at ICCF4.

AUTHORS' ABSTRACT

This paper reports two groups of experiments on cold fusion in a titanium lattice. A kind of solution containing the $D_2O$ and a little $H_2O$ is used in the first group of experiments and we could not observe any increase in temperature in the Ti-rod after more than ten days, and then we found that the capability of Ti-rod to absorb H atoms is stronger than the capability of Ti-rod to absorb D atoms.

In the second group of experiments, the electrolyze solution is pure $D_2O$ and the "excess heat" phenomena occurs after six days. The increase in temperature in the middle of Ti-rod reached 0.5°C and the part of button of $D_2O$ reached 1.2°C. After then, we found that the X-ray diffraction spectrum of Ti-rod causes change and some spectra lines of Ti-rod are unknown. On the other hand, the surface of Ti-rod becomes much more brittle after "excess heat".

## INDIA - PROTON BEAM AND Pd

A.R. Chindarkar, A.S. Piathankar, A.M. Bhagwat, G.R. Naik., S.K. Iyyengar and M. Srinivasan (Accelerator and Pulse Power Division, BARC, Bombay), "Observation of High Energy (≈ 1 MeV) Charged Particles during Implantation of 5 kev Protons on Pd and Ti Foils using CR-39 SSNTD's," presented at ICCF4.

AUTHORS' ABSTRACT

In recent years various authors, including Chambers and Cecil, have observed anomalous emission of high energy charged particles from deuterium/palladium and deuterium/titanium systems. The understanding of this anomalous emission can prove to be a precursor in unravelling the mystery of 'Cold Fusion'. This paper presents the evidence of anomalous emission of high energy charged particles from hydrogen/palladium systems as well and shows that this phenomenon is not unique to deuterium/solid systems only. In this experiment the thin foils of palladium (8mm x 12mm x 0.1mm) and titanium (8mm x 12mm x O.025mm) are loaded with hydrogen ions (protons) by bombarding ~5 kev ion beam over a prolonged period of 1 to 15 hours. The ion beam is produced by a locally developed RF ion source. The diameter of ion beam is 10mm and the ion current density is 0.1 $mA/cm^2$ at the target which is placed at a distance of 12cm from the extracting aperture (of diameter ~3mm). The target is placed at an inclination of 45° to the incident beam and the SSNT detector is placed at 90° to the incident beam.

For the measurements of low level, high energy charged-particle emission, integrating property of SSNTDs was used. The SSNTDs technique has been recently refined to make low level measurements more reliable. In this technique CR-39 SSNTDs films are pre-etched so that the existing level of background and overall quality of films are known. Final etching after exposure helps to reveal the number of tracks (events) due to the charged particle emitted. In order to know the energy spectrum of the charged particles, the detector was covered by aluminum foil absorbers of various thickness namely 6 μm, 8 μm and 12 μm having energy range of 0.6 MeV, 0.7 MeV and 0.9 MeV respectively for protons. It is, however, to be noted that tracks (events) on charged particle on Ca-39 were observed only when irradiation of Pd or Ti target was in progress (on-line), while no tracks were observed after irradiation (off-line).

We show the results for few samples irradiated by proton beam (~ 5 kev) for various time periods. The CR-39 film detector was half bare and half covered with Al-absorber in a single run. The statistical value $>3\sigma$ was taken as positive indication of high energy charged particles emission.

From the analysis of the results and the subsequent experiments carried out on large number of samples, the following conclusions can be drawn:
(1) The energy analysis carried out by foil attenuation technique indicates that the charged particles up to 0.9 MeV, to which the measurements are restricted, are definitely emitted from the target. The possibility of the emission of charged particles >0.9 MeV also exists.
(2) Reproducibility of the experimental observation is extremely good, i.e., 8 out of 10 samples of Pd and 2 out of 3 samples of Ti give positive results ($>3\sigma$). One Gadolinium sample also gave positive results.
(3) The Pd samples which were coated with gold metal of about 200 Å on one side (back side of the sample to be irradiated) to prevent out diffusion and allow build up of proton density inside the metal-lattice, showed that emission of particles >0.7 MeV was more prevalent and particles of lower energy were not observed.
(4) The estimated emission rate of charged particles is between 0.1 to 2 particle/min.

## ITALY - TOFUS EXPERIMENTS

M. Agnello*, E. Botta, T. Bressani, D. Calvo, C. Fanara, A. Feliciello, F. Iazzi* (Ist. Naz. di Fis. Nuc., Torino, *also Dip. di Fis. del Politec. - Torino), "Results and Perspectives of the TOFUS Experiment in Neutron Emission from $D_2$/metal Systems," presented at ICCF4.

AUTHORS' ABSTRACT

The technique of the neutron detection by means of the measurement of the Time of Flight (TOF) in the double scattering has been successfully used in TOFUS experiment at the INFN Laboratories of Turin (Italy).

Signals of a neutron emission from the (gas) loaded system $D_2$/Ti have been observed with statistical significance from 2.5 up to $5\sigma$. Samples of Ti metal differently worked by the manufacturer gave different neutron emission rates although they were operated in the same thermodynamic conditions. On the other hand no significant

emission was observed for $D_2$/Pd system submitted to analogous thermodynamic treatments inducing α-ß phase transitions.

Recently the detector has been slightly modified in order to improve the neutron energy resolution from 1 to 0.8 MeV/c. The first set of measurements after this improvement has been devoted again to the $D_2$/Ti system. A neutron emission has been observed under well defined "external" conditions: pressure of the gas around the $D_2$/Ti system, temperature of the metal, original structure of the Ti sample, and time elapsed from the beginning of the thermodynamic cycles were very accurately controlled by means of the vacuum system around the cell. The analysis at the present is still in progress: nevertheless the indication of a dependence of the neutron emission on some of the above conditions seems visible.

Further developments of the measurements are foreseen for the next year. They concern a) the improvement of the detector and b) the change of the gas loading technique. The first goal will be reached by modifying the vacuum system in order to be able to retrieve an amount of the gas operated in the thermodynamic cycles and for measuring the He contents by a high resolution mass spectrometer. In this way the occurrence of the reaction:
$D + D \rightarrow {}^4He + \gamma$
could be correlated with the other one:
$D + D \rightarrow {}^3He + n$ up to now measured.

In order to reach the second goal a technique based on the Cohen effect in the Pd/Pt junctions in presence of weak currents is now explored. Different geometries of wire sequences Pd/Pt/Pd/Pt... are designed at the INFN Laboratories and will be tested in the next future. This new kind of cell will replace the present one in front of the neutron detector and will allow to ascertain whether the neutron emission from $D_2$/Pd system occurs with a high concentration loading of the metal.

### ITALY - OKLO ISOTOPE ANOMALIES

W.J.M.F. Collis (Boglietto, Italy), "Oklo Isotope Anomalies and Cold Fusion," presented at ICCF4.

AUTHOR'S ABSTRACT

A small site in the extensive Oklo uranium mine in Gabon, Africa is believed to have been a natural reactor where uranium fission took place over a period estimated to be 600,000 to 3,500,000 years during pre-Cambrian times. This is confirmed by the presence of fission products and a depletion of $^{235}U$. In some zones there is an excess of $^{235}U$ relative to $^{238}U$. The conventional view suggests that $^{239}Pu$ created by fission derived neutron absorption of $^{238}U$ decays directly to $^{235}U$ with a half life of 24,360 years. There is also a depletion of deuterium in water derived from Oklo rocks. Normal D/H ratio is 150 ppm but at Oklo it is reduced to about 127 ppm. Shaheen et al. have made an alternative suggestion that both uranium and hydrogen isotope anomalies might be due to neutron swapping reactions:
a) ${}^2H + {}^{238}U \rightarrow F_1 + F_2 + {}^1H + xn$
b) ${}^2H + {}^{238}U \rightarrow {}^{239}U + {}^1H$
Conspicuous by their absence at the Oklo reactor site are those water soluble fission products such as cesium, barium, etc. This suggests that water has been cycling through the natural reactor site. It is probable that the deuterium anomaly also exists in the water of neighboring rocks which did not host any fission. It is suggested that the anomalous isotope ratios at Oklo are best explained by photo-disintegration of deuterium due to gamma rays generated by radioactive decays in the uranium ore. Consequently, the Oklo isotope anomalies do not lend support to cold fusion.

### JAPAN - DEUTERON BEAMS & Ti, Pd

Toshiyuki Iida, Morio Fukuhara, Sunarno, Hiroyuki Miyamaru and Akito Takahashi (Dept. Nuc. Eng., Fac. Eng., Osaka Univ., Osaka), "Deuteron Fusion Experiment with Ti and Pd Foils Implanted with Deuteron Beams II," presented at ICCF4.

AUTHORS' ABSTRACT

Deuteron implantation experiments on Ti and Pd foils have been made for the examination of the "cold" deuteron fusion reaction. In the center of a target chamber fitted to a 250 keV deuteron accelerator, a Ti or Pd foil sample was set to face toward 3 nsec pulsed deuteron beams collimated with a 3 mmϕ aperture. A Si-SSD was placed behind the foil to detect high energy charged particles emitted from the foil by the supposed deuteron fusion reactions. In the 243 keV deuteron implantation experiments for 3, 5 and 8 μm Ti foils, two unusual peaks around 7 and 3 MeV were measured except the well known D-D reaction, and they are considered to be helium and proton, respectively because of their energy reduction characteristics in the foils. A typical energy spectrum of charged particles emitted from the 5 μm Ti foil is shown. After checking the possibility of other deuteron-induced nuclear reactions due to the surface contamination of the foils, we will give details about the relation between the obtained spectra and the multibody fusion model by A. Takahashi.

### JAPAN - NEUTRON & TRITIUM ANOMALIES

Yasuhiro Iwamura, Takehiko Itoh and Ichiro Toyoda (Adv. Tech. Res. Ctr., Mitsubishi Heavy Ind., Ltd., Yokohama), "Observation of Anomalous Nuclear Effects in $D_2$-Pd System," presented at ICCF4.

AUTHORS' ABSTRACT

Neutron emissions and tritium productions have been observed when deuterium gas is released from deuterated palladium metals by heating. It shows that some anomalous and unexpected phenomena occur in deuterium-palladium system as reported in many papers on cold fusion.

Palladium samples loaded with deuterium gas were prepared as follows. Palladium sheets (25x25xlmm) were heated in the air at 573K for an hour and cooled down to room temperature (~ 298K) in deuterium gas. After loading (D/Pd ~ 0.66), we kept the deuterated palladium samples in liquid nitrogen temperature (77K) for several hours. The samples were brought back to room temperature environment, and then gold thin-film was vapor deposited onto both surfaces of the deuterated palladium in order to reduce the rate of deuterium gas release.

The sample was introduced into a vacuum chamber and set on a heater located in it. The chamber is equipped with He-3 neutron detectors, a NaI scintillation counter for gamma-ray detection and a high-resolution quadruple mass spectrometer for gas analysis. All these devices are located in a clean-room where temperature and humidity are always controlled at constant levels.

We heated the sample and made deuterium in the palladium metal released out in order to induce anomalous nuclear effects. If we heat the deuterated palladium sample kept at room temperature up to about 400K, deuterium atoms contained in the palladium metal move toward the gold thin-film surfaces of the sample and then release out as deuterium gas. We observed neutron emissions and tritium productions several times during deuterium gas desorption from the samples by heating.

We show an example of experimental results on neutron emission. With heating the sample up to 400K, we find that total pressure in the vacuum chamber increases and decreases rapidly. Simultaneously, we observe a clear and prominent neutron emission peak. The emission rate is estimated $4.0 \times 10^{2}$ (neutron/sec) by using a Cf-252 calibration source, and that corresponds to the rate of $3.0 \times 10^{-20}$ (event/sec/d-d pair).
We show another experimental result on tritium production. DT peak detected by the mass spectrometer after heating reaches about six times as large as the deuterium gas background. It means that a certain tritium production mechanism exists in our experimental process.

Recently we have introduced charged particle detectors to our experimental system. Experimental results on charged particle detection, in addition to various methods for increasing nuclear products, such as way of making samples, heating temperature, will be described.

## JAPAN - DEUTERON BOMBARDMENT OF Ti

J. Kasagi, T. Ohtsuki (Nuc. Sci. Lab., Tohoku Univ., Sendai), K. Ishii (Cyclotron & RI Ctr., Tohoku Univ.) and M. Hiraga (Dept. Chem., Tohoku Univ.), "Anomalous Protons and α-particles Emitted in 150-keV Deuteron Bombardment on Highly Deuterated Ti," presented at ICCF4.

AUTHORS' ABSTRACT

We have studied charged particle emission in the bombardment of 150-keV deuterons on highly deuterated Ti. In the bombardment on $TiD_x$ with large x (x ~ 1.3), energetic protons with energies up to ~17 MeV were found for the first time, although no energetic protons were detected for smaller x. The characteristics of the high energy proton structure are these: a broad bump ranging from 12.5 to 16.5 MeV, a sharp peak at 14.1 MeV, and a continuum up to ~17 MeV where the bump and the peak are superimposed. The sharp peak was interpreted as protons emitted in the $^3He(d,p)^4He$ reaction; the interpretation requires an anomalous concentration of $^3He$ in the target before the bombardment began. However, we have had only four cases which show the peak clearly, out of more than 100 bombardments on various $TiD_x$. By contrast, the bump and the continuum always appear in any measurements on $TiD_x$ as long as x > 1. For the broad bump, protons are interpreted to be emitted in the $D(^3He,p)^4He$ reaction which sequentially occurs following the primary $D(d,^3He)n$ reaction.

The fact that protons are observed with energies up to ~17 MeV is really anomalous. It is impossible from a consideration of Q-values that such high energy protons are due to reactions of the incident deuterons with Ti and contaminants in the target. None of the secondary reactions with neutron, triton or $^3He$ can produce such high energy protons. Therefore, the question is the origin of the continuous protons existing up to ~17 MeV.

Alpha-particle emission in the bombardment is quite anomalous, as well; we have observed α particles as seen in paper, which shows a scatter plot of ΔE vs E measured at 135° in the bombardment on $TiD_x$. In the lowest part of the figure, protons from the D(d,p)T reaction as well as their pileups are seen as a heavy locus. In addition, a broad locus consisting of several tens of events are observed at larger ΔE region, which was actually assigned to be α-particles based on the observed energy loss. Energy spectra of the α-particles were deduced by setting a window on the two-dimensional spectra; α particles are continuously distributed up to ~6.5 MeV.

The yield depends strongly on the deuteron density. This indicates that the particles are not produced in secondary reactions of the products of the primary D+D reaction, i.e., p, n, t and $^3He$, except for the sequential reaction involving another deuteron in the target. The spectral shape of emitted α-particle in the sequential reactions in which the $D+^3He \rightarrow \alpha+p$ ($D+T \rightarrow \alpha+n$) reaction follows the $D+D \rightarrow n+^3He$ (p+T) reaction was calculated using the same program used to calculate the proton spectrum. The result gives the bump also in the α-particle spectrum. In this case, however, the expected bump lies at lower energy region than observed. Thus, the observed α-particles are not explained as the products of the sequential reaction, either.

We have speculated that the protons and α-particles are emitted in the reaction where the bombarded deuteron reacts with two deuterons in the target, without forming a real intermediate state. The incident deuteron, first, interacts with a deuteron to form a virtual intermediate state, which subsequently interacts with another deuteron and produces neutron, proton and particle. In this case, the available energy is shared with the three particles in the final state; the maximum energy of each particle can be larger than that of the sequential reaction. We have calculated the phase spaces of protons and particles being available in the $D+D+D \rightarrow p+n+\alpha$ reaction (Q = 21.62 MeV). The calculation explains both proton and α-particle spectra very well. Thus, the observed spectra indicate the possibility that the incident deuteron interacts with two other deuterons in the target to produce n, p and α, simultaneously. This interpretation needs an anomalously large enhancement factor, at least, of $\sim 10^{12}$.

## JAPAN - CATALYSIS AND COLD FUSION

Hideo Kozima (Dept. Phys., Fac. of Sci., Shizuoka Univ., Shizuoka), "A Phenomenological Model of the Cold Fusion in Pd (Ti)- D System," presented at ICCF4.

AUTHOR'S ABSTRACT

The most controversial topic in the past several years in Physics has been cold fusion. Depending on the importance of the news in terms of scientific, technological and commercial meaning, the styles of the announcement of the news were rather irregular to use mass media than academic journals from the outset. In these more than four years from the first news, many experimental and theoretical works have been published in academic journals and in the proceedings of International Conferences. There are, however, wide diversity of the experimental results and uncertainty of conditions to get positive results for cold fusion. One of the most fine experiments done in Japan (Kamiokande) with reduction of background radioactive effects could not prove the existence of the Cold Fusion in the Pd-D system.

Some eager opponents to the possibility of cold fusion have declared that the Kamiokande experiments, along with some others, denied cold fusion. They have attacked researchers of cold fusion as believers in a phantom. Science, however, is not such a thing as the opponents believe in. The scientists do not believe in experimental results but give some credence in them by reserving to say NO at any time if necessary. These words are not necessary to say in usual situation but are in the unusual period after the Third International Conference on Cold Fusion (Nagoya, 1992) when unscientific sentences were distributed in the form of a letter among physicists.

We now want to discuss fundamental features of Cold Fusion phenomenologically on a basis of existing experimental data.

One of the most remarkable features of the phenomena is the stochastic character of the occurrence of the neutron burst and the sudden heat production. **These features of the phenomena brings the catalytic nature of chemical reactions to our remembrance. Something might be working as catalyst in Cold Fusion.** It is also remarkable that Cold Fusion occurs scarcely when the ambient radioactivity is reduced markedly as in the Kamiokande experiment. Not saying other features of Cold Fusion such as done by Yamaguchi et al., the characteristics mentioned above suggest a catalyst nature of the phenomena originating probably in the ambient radioactive substances.

Assuming the catalytic nature of Cold Fusion is essential, we take up a mechanism of the Cold Fusion induced by the background neutrons in the palladium (titanium) metal occluded with deuterium and calculated probability of the induced fusion. The result taking into account of a solid state effects shows it is possible that the Cold Fusion reported hitherto could be induced by this mechanism. Other causes of the induced Cold Fusion might be relevant with ambient gammas and cosmic rays.

The neutrons from ambient source enters into the palladium metal saturated with deuterium by a flux density $N_a\ cm^{-2}s^{-1}$ with energy $\varepsilon$.

The incident neutrons collide with α deuteron in the sample metal with a collision cross section $\sigma_0(\varepsilon)$ giving energy

$$E_0(\theta) = (4/9)\,\varepsilon \cos^2 \theta$$

to it in the direction $\theta$ from the incident neutron direction. The deuteron recoiled with energy $E_0\ (\theta)$ collides with another deuteron in the metal fusing into $^4$He with a cross section $\sigma\ (E_0)$. Flux density of background neutrons observed and sample sizes used in the experiments give reasonable amounts of fusion events in those experiments.

## JAPAN - ELECTRICAL DISCHARGE C.F.

Takaaki Matusmoto (Dept. of Nuc. Eng., Hokkaido Univ., Sapporo, Japan), "Cold Fusion Experiments by Using Electrical Discharge in Water," presented at ICCF4.

AUTHOR'S ABSTRACT

The Nattoh model earlier predicted that cold fusion is based on a new fusion reaction, called "hydrogen-catalyzed fusion reaction". This reaction easily takes place when a hydrogen-cluster is compressed by itself. The compression can be enhanced by using electrical discharge. Cold fusion experiments by using the electrical discharge in water are described here.

Metal wire electrodes (Pd, Ni and Pt; 0.5 - 2.0 din) were vertically or parallely located in ordinary water mixed with 0.6 mol/l potassium carbonate. The distance between the electrodes was about 3 to 5 min. AC shots (about 100 V, 20 60 msec) were applied on the electrodes through an electrical switch. Pictures of explosions were taken with a microtelescope and VTR. Furthermore, nuclear emulsions were located outside a glass cell to record emitted particles.

The following observations were made:

1. Explosions in water which are caused by the hydrogen-catalyzed fusion reactions take place before a plasma state is formed by the AC shots,

2. Many extraordinary traces were found indicating gravity-decays of multiple neutrons, the production of tiny blackholes and stars, etc.

3. Wires exploded.

The mechanisms of cold fusion by using electrical discharge in water are discussed based on the Nattoh model.

## JAPAN - DEPOSITION BEHAVIOR OF Li

Shinya Miyamoto, Keisuke Sueki, Masatoshi Fujii, Toshiaki Shirakawa, Masami Chiba (Faculty of Sci., Tokyo Metro. Univ.), Takayuki Kobayashi (Sch. Hygenic Sci., Kitasato Univ.), Minoru Yanokura, Michi Aratani (Inst. Phys. & Chem. Res. {RIKEN}), and Hiromichi Nakahara (Tokyo Metro. Univ.), "Movement of Li During Electrolysis of 0.1 M-LiOD/$D_2O$ Solution," presented at ICCF4.

AUTHORS' ABSTRACT

Since March 1989, when M. Fleischmann & S. Pons and S. Jones et al. reported the cold fusion phenomena which they claimed to proceed through next reactions, many scientists tried to repeat this experiment.

$d + d \rightarrow {}^3He\ (0.82\ MeV) + n\ (2.45\ MeV)$ <1>

$d + d \rightarrow {}^3H\ (1.01\ MeV) + p\ (3.02\ MeV)$ <2>

$d + d \rightarrow {}^4He + gamma + 23.4\ MeV$ <3>

But because of difficulty of reproducing the subtle experimental conditions, the truth of cold fusion has not been ascertained yet. In the previous work, we searched for protons that were expected from reaction <2>, but only the upper limit of $1.35 \times 10^{-24}$ was obtained.

We reported last year in the Nagoya conference that when an electrolysis was performed for the 0.1M-LiOD/$D_2O$ solution with a Pd cathode, Li in the electrolyte was deposited into the cathode. This work investigates dependence of the depth profile and concentrations of Li, D, and H inside the Pd cathode on various conditions of electrolysis. Elastic Recoil Detection Analysis (ERDA) was applied for detection. Possible generation of the excess heat was also monitored by a newly designed cell.

Experiments: The electrolysis cell is shown. This cell is thermally insulated from environment, and it was cooled by the forced flow of water through a copper pipe. The difference of the water temperature between IN and OUT was measured. Electrolysis was mostly performed at a constant cathode voltage with respected to a reference and influence of conditions of electrolysis on the deposition behavior of Li was investigated. The 0.5%-Pd alumina pellets (NE Chemcat Co., Lot No.: 256-18130) were fixed above the electrolyte solution inside the cell as a recombination catalyst of $D_2$ and $O_2$ gas into $D_2O$. The current, input voltage, reference voltage, and the temperature of the electrolyte and the ambient, and difference of IN and OUT of cooling water were monitored.

After electrolysis, $Ar^{6+}$ beams from the heavy-ion linear accelerator of RIKEN (RILAC) were used for the analysis of the depth profiles and concentrations of Li, D, and H in the Pd cathodes (10X10X3 mm; Tanaka Kikinzoku Co.) by ERDA. The set up in the chamber is shown in Fig.2 of the paper. The detector was calibrated by the Rutherford Front Scattering (RFS) of Ar by Pd.

Results: The conditions of electrolysis in each run are reported. One typical examples of an ERDA spectrum is shown. The peak energy of Li and H from the surface is 11.2MeV and 2.6MeV, respectively. The tailing on the lower energy side of each peak represents the scattering events from the inner part of Pd. Detailed analysis of depth profiles and concentrations of Li, D,and H is still in progress.


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## JAPAN - TRITIUM PRODUCTION WITH Ni

Reiko Notoya (Catalysis Research Ctr., Hokkaido Univ., Sapporo, Japan), "Alkali-Hydrogen Cold Fusion Accompanied with Tritium Production on Nickel," presented at ICCF4.


AUTHOR'S ABSTRACT

This paper described the results of the quantitative measurements of the amounts of produced tritium and other fusion products during the electrolysis of light and heavy water-solutions of $K_2CO_3$ by use of specially designed porous nickel cathodes.

These cathodes are made of the same material that was used for the observation of the extraordinarily large amount of heat evolution (the excess heat: 200-360% for the input power) as described in the previous paper.

The following reactions were proposed by Fleischmann and Pons, and Takahashi et al., as the most expected ones to produce tritium:

$${}^2d + {}^2d \rightarrow {}^3t + {}^1p, \quad (1)$$

$${}^2d + {}^2d + {}^2d \rightarrow {}^3He + {}^3t. \quad (2)$$

These reactions would be carried out in the solid of the electrode metal and tritium species might diffuse towards the electrode surface.

The most part of the tritium product of the cold fusion which remains in the solution as PTO but does not go outside the cell as $T_2$, is quantitatively determined by the following ways. Because the hydrogen evolution reaction on nickel in alkaline solutions is occurring according to the recombination mechanism:

$$M^+ + e^- \rightarrow M(I)\ , \quad (3)$$

$$M(I) + H_2O \rightarrow M^+ + OH^- + H_a\ , \quad (4)$$

$$2\ H_a - n \rightarrow H_2\ , \quad (5)$$

where M(I) and $H_a$ denote the intermediates of alkali metals forming the intermetallic compound with nickel and the adsorbed or absorbed hydrogen on or in nickel, respectively.

Consequently, the tritium species absorbed or adsorbed in(on) nickel at the boundary layer undergoes more easily the ionization than the recombination through the rate determining step.

Electrolysis in each solution of 20 or 30 ml was carried out for 6-100 hours galvanostatically and after that the tritium content in the solution was determined by Liquid Scintillation Counter.

The values of tritium content in the solutions electrolyzed for longer than 6 hours become constant. There is a roughly linear relation between the amount of tritium produced by electrolysis and the excess heat evolving during the electrolysis. The electrolysis of heavy water produces about 100 times as much tritium content as the light water. However, the ratio of each tritium content does not correspond to the ratio of each deuterium concentration between both solutions.

The greatest increase of tritium content attained 394 Bq/20 ml in 99.8% deuterium solution, but that, 9 Bq/20 ml in the light water-solution.

It was evident from the results described above that the produced amount of ${}^3t$ is far less than that of calcium product, but it is not easily to say that the tritium formation reaction is not due to the heat evolution.

In this paper the possibility of more complicated alkali-hydrogen cold fusion is discussed by use of the results of ICP-MS analysis.

## JAPAN - IRON ATOMS ON GOLD

Tadayoshi Ohmori and Michio Enyo (Catalysis Res. Ctr., Hokkaido Univ., Sapporo, Japan), "Detection of Iron Atoms on Gold Electrodes Used in Electrolysis of $H_2O$ and $D_2O$ in Neutral and Alkaline Media," presented at ICCF4.

AUTHORS' ABSTRACT

In a previous study we observed the excess heat evolution ranging from 0.2 to 1 W during the electrolysis on various metal electrodes in alkali metal salts ($K_2CO_3$, $Na_2SO_4$ etc.) / $H_2O$ systems. The amount of the excess heat reached typically 1 W (20 % excess of input energy) on tin and gold electrodes. This heat was thought to be due to a result of some nuclear fusion reaction. In this study, we tried to detect any products produced during such excess heat evolution in order to obtain insight into the nuclear fusion reaction that may be occurring in this system. The identification of the product was carried out by AES spectroscopy with the hope that they should remain at the vicinity of the electrode surface.

The test electrode used was a gold sheet of ca. 5 $cm^2$ (99.99%, Fe < 1 ppm) strained by scratching its surface by a glass edge. The counter electrode was a platinum net (99.98 %, Fe < 16 ppm). Two types of electrolytic cell (Pyrex-glass, and Teflon cells) were used. Teflon cell was used in $K_2CO_3/H_2O$ system. All the electrolyte solutions were prepared from Merck reagents (Suprapur) and MQ water. Electrolysis was performed for 7 days by continuously passing a constant current of 1 amp. The electrode surface after electrolysis was washed thoroughly with MQ water, and was analyzed by means of AES spectroscopy (ANELVA AAS-200).

A notable amount of iron atoms were detected. Figure 1.[in the paper] shows a typical example of AES chart observed with the electrode used in $K_2CO_3$ / $H_2O$ system. The outermost layer is composed of Pt, Fe and O atoms, whereas Au atom is not seen. Pt atoms are likely to originate from the counter electrode. Oxygen atoms observed are probably present together with iron atoms since the oxygen signals became invisible only when iron signals disappeared.

Such electrodes were then subjected to $Ar^+$ ion bombardment. After it was performed, the signals Pt and Fe decreased, while the signal of Au appeared which increased rapidly with the bombardment time. After the bombardment of 3 - 4 minutes, all the signals except for Au were lost. From the results in Fig. l, we could estimate approximate depth of Fe distribution: it amounted some ten layers from the electrode surface. Fig. 2 shows results obtained in 0.5 M $K_2CO_3/H_2O$, 0.5 M $Na_2SO_4/H_2O$ and $Na_2SO_4/D_2O$ systems. **As shown, 40% of the outermost layer atoms consisted of Fe atoms in the case of both $K_2CO_3/H_2O$ and $Na_2SO_4/H_2O$ systems.** However, the decrease of iron distribution with depth is much smaller in the former system, i.e. the total amount of Fe atoms is much larger. On the other hand, in $Na_2SO_4/D_2O$ system, 80 % of the outermost layer atoms are consisted of Fe atoms, but the decrease of its distribution with depth is nearly the same as in the case of $Na_2SO_4/H_2O$ system.

The total amount of iron estimated in these systems are listed in Table 1 [in the paper]. The excess heats evolved on Au electrode in various systems, observed in separate runs, are listed in Table 2. The total amount of Fe ranged between 3.3 x $10^{16}$ and 1.2 x $10^{17}$ atoms, whereas the excess heat ranged from 908 to 524 mW in $K_2CO_3/H_2O$ system or was 334 mW in $Na_2SO_4/H_2O$ system. It seems likely from these data that the extent of iron atom formation and excess heat evolution do not depend significantly on the nature of alkali metal atoms used.

The amounts of Fe observed are much larger than those possibly contained in reagents used (ca. 7 x $10^{14}$ atoms for $Na_2SO_4$ and 3 x $10^{15}$ atoms for $K_2CO_3$) or originated from Pyrex glass materials. Is by its partial dissolution (ca. 2 x $10^{14}$ atoms for $Na_2SO_4$). This may suggest that the iron formation reaction could be responsible for the excess heat evolution. It is not impossible to write down nuclear transformation reactions producing Fe from two or three $OH^-$, but that is too much speculative. It may be added though that the amount of Fe observed can be shown to be in comparable order of magnitude as compared with the total amount of excess heat evolution.

## JAPAN - LITHIUM BARRIER

Makoto Okamoto, Yuri Yoshinaga and Takehiro Kusunoki (Res. Lab. for Nuc. Reactors, Tokyo Inst. Tech., Ookayarea, Meguro-City, Tokyo), "Behavior of Key Elements in Pd for the Solid-State Nuclear Phenomena Occurred in Heavy Water Electrolysis," presented at ICCF4.

AUTHORS' ABSTRACT

As has been described in our previous paper (ICCF-3), lithium in the heavy water electrolysis works as a key element to form a barrier to disturb the back diffusion of deuterium to the electrolyte and to accumulate deuterium anomalously in the surface of Pd electrode. In the previous paper, the role of lithium was discussed based on the SIMS analysis data of Li, Pd, and d in the electrodes with the neutron emission and those without neutron emission. The finding in the previous paper is that the depth profiles of Li and d are monotonous and that of Pd is flat from the surface to the bulk of Pd electrode with no neutron emission while the profiles have some irregular structures in the Pd electrodes with positive neutron emissions.

In the present work, the behavior of the other interesting elements such as Si, Al and Na along with the above three elements has been investigated to elucidate their roles for the neutron emission and the excess heat generation in the present $D_2O$-LiOD-Pd electrolysis.

The tested electrodes are as follows.
(1) Pd plate as received.
(2) Pd electrodes used for $H_2O$-LiOH electrolysis with no positive evidence.
(3) Pd electrodes used for $D_2O$-LiOD electrolysis with no positive evidence.
(4) Pd electrodes used for $D_2O$-LiOD electrolysis with neutron emission.

(5) Pd electrode used for $D_2O$-LiOD electrolysis with neutron emission and excess heat generation.
(6) Pd electrode used for $D_2O$-NaOD-Pd electrolysis with neutron emission.

The analysis of the questioned elements was performed on a SIMS system as described in the previous paper. The electrodes with no neutron emission gave typical monotonously deceasing profiles of d, Li and Pd as reported in the previous paper, and also of Si and Al, while the profiles from the electrodes with neutron emission and with neutron emission + excess heat generation have very irregular profiles for all the analyzed elements.

We found a very significant point on the concentration of d and Li in the surface of electrodes up to 3.0 µm to be in a clear sequence of the electrodes with no nuclear event, (1) to (3) < those with neutron emission (4) <that with neutron emission and the excess heat generation (5).

The concentrations are relatively compared by normalization to the secondary ion intensity of Pd from the bulk of the Pd electrodes. In the case of (6), we examined a $D_2O$-NaOD-Pd system, resulting a positive neutron emission. The profiles of Na and Si have the irregular structures as in the above positive events and those of d, Al, and Pd have weak but appreciable structures, and the relative concentration of d was almost same as of other cases where the neutron emission and/or the excess heat were observed.

As the conclusion, it may be said that for the neutron emission and excess heat generation, anomalous deuterium accumulation in the surface of Pd electrode should be realized and the accumulation might be attributed to the formation of the intermetalic compounds of Li with Pd, Si and Al. The formation of these intermetalic compounds may cause the increase of the overvoltage in the process of electrolysis.

## JAPAN - CLOSED CELL - A.C. METHOD

Noboru Oyama, Hiroshi Hirasawa, Tetsu Tatsuma and Nobushige Yamamoto (Dept. Appl. Chem., Tokyo Univ. of Agric. and Tech, Tokyo), "Calorimetry of $D^2O$ Electrolysis Using a Palladium Cathode in Closed Cell System. AC Current Electrolysis Method," presented at ICCF4.

AUTHORS' ABSTRACT

Since the observation of excess heat generation in $D_2O$ electrolysis using a palladium cathode was reported by Fleischmann et al., we have addressed ourselves to the evaluation of excess heat. Although open cell systems have been used for excess heat observation in many cases, the evaluation procedure for excess heat in the open system is complicated because several parameters must be considered and thus the evaluated excess heat may contain some error. That is, heat generation through the recombination of $D_2$ and $O_2$, the heat uptake through vaporization of $D_2O$, heat loss by radiation or conduction, and so forth must be taken into account. Therefore, we have employed a closed cell system, in which $D_2$ and $O_2$ generated are recombined on a catalyst so that the errors contained in the open system are much smaller and excess heat can be evaluated more precisely.

In the present work, we envisage establishing an AC current electrolysis method. In this method, DC current (cathodic current on Pd electrode) and AC current were overlapped.

Electrolysis of $D_2O$ (Isotec) containing LiOD (0.1 M) was performed with a two electrode system in a twin cell. A palladium rod (2.0 mm in diameter and 5.0 mm in length) of >99.9% purity (Tanaka Kikinzoku, Japan) and a platinum gauze were used as the cathode and anode, respectively. The other twin cell as a reference was filled with a solution of the same amount and the same composition as was the electrolytic cell. Those twin cells were closed and set in a calorimeter (model MM 5111, Tokyo Riko, Japan) which is kept at 8.0°C. Difference in generated heat between the twin cells was measured and transferred to the computer every 10 seconds together with other parameters, applied voltage and current, for subsequent data processing and analysis. All $D_2$ and $O_2$ generated and liberated to a gas phase were recombined on a catalyst, palladium black supported on a platinum wire.

Figure 1 shows input current (A) and input and output heat (B) observed in $D_2O$ containing 0.1 M LiOD. Excess heat for each cycle was evaluated on the basis of the following equation: $R_{ex}$ (%) = $[(J_{out} - J_{in})/J_{in}]$ X 100, where $J_{out}$ and $J_{in}$ are average output and input heat for each cycle. Thus evaluated $R_{ex}$ is plotted in Figure 2A and B. As can be seen, these curves can be divided into stable and unstable regions, period of which is 50-150 h. In the unstable regions, exothermic and endothermic behavior (3% at the most) is observed. This behavior may include temporary uptake and release of $D_2$. Although it is not clear whether the unstable region includes excess heat generation or not, the present method was found to be effective in leading the system to an unstable state. Loading amount of $D_2$ has never been considered.

## JAPAN - HEAT MEASUREMENT

Ken-ichiro Ota, Hideaki Yoshitake, Osamu Yamazaki, Masaki Kuratsuka, Kazuhiko Yamaki, Kotoji Ando, Yoshihiro Iida and Nobuyuki Kamiya (Dept. Energy Eng., Yokohama Nat. Univ.), "Heat Measurement of Water Electrolysis using Pd Cathode and the Electrochemistry," presented at ICCF4.

AUTHORS' ABSTRACT

The excess enthalpy during the heavy water electrolysis using Pd cathode mainly in LiOD solution has been reported by the several groups. However, the complete reproducibility has not been obtained in any group. In order to get the reproducibility of this phenomena, the electrochemistry especially in Li content alkali solution as well as the material science of Pd cathode is very important.

In our group the heat balances during the heavy water electrolysis have been measured by the flow calorimeter and we reported some

results at the former meeting (ICCF3). In this paper our recent results of heat measurements will be reported.

In order to understand the electrochemical characteristics of Pd cathode in Li containing solutions, the behavior of Li and the hydrogen absorption should be elucidated, since Li can be easily included into Pd metal. In this report the overpotential of the Pd cathode in Li containing solution and the amount of hydrogen absorption in Pd cathode will be also reported related to the Li inclusion.

Heat Measurement

The heat balance measurements have been carried out in an acrylic electrochemical cell with the recombination catalyst to keep the system thermochemically closed. Using Pd catalyst, the recombination reaction proceeded completely up to 4 A. The flow calorimetry technique was applied; copper tube surrounded the cell where cooling water flows, picking up the heat generated by the electrolysis. The increase of cooling water temperature was measured and the heat output was calculated. We adopted the constant power generator for the electrolysis and controlled the cooling water temperature 296°K or 278°K at the entrance. We used 99.9% Pd or 90% Pd - 10% Ag alloy for cathode and 99.9% Pt for anode. The electrolytes used were LiOD(1.0 or 0.1 M) heavy water solution and LiOH(1.0 or 0.1 M) light water solution. We did 16 runs of heavy water electrolysis and 4 runs of light water electrolysis. Among them we detected the excess heat three times only in heavy water and using the mechanically treated Pd cathode. The typical mechanical treatment is compression with 640 kgf and with six notches of 0.2 mm width and 2 mm depth.

The result is shown of heat balance for mechanically treated Pd-Ag alloy. The excess output power started to be observed after 1150 hrs. This state held for 220 hrs. and went back to the balanced state again. The average output power for this period was 6.5%, and the maximum was 13%. The integrated excess energy over this period was 3.6 MJ. Such an excess energy was observed in another run. The fluctuation of the cell voltage and the cell current in the previously mentioned run is shown. Since we are using the constant power electrolysis, the cell voltage and the current changes simultaneously. The cell voltage decreased steeply from the beginning until 1000 hrs. and then increased. This tendency was observed commonly during the three runs where the excess heat was observed. This voltage (current) change might initiate the excess heat generation.

Hydrogen Absorption and Li Inclusion into Pd Cathode

We measured H/Pd ratio as the sum of the gas volume evolved from Pd after the electrolysis and the weight of remaining hydrogen in Pd. We used 99.9% Pd foils which was annealed at 1273°K before use. The temperature of electrolytes was kept at 298 ± 1°K.

The relationship is shown between the electrolysis time and the amount of hydrogen absorbed into Pd cathodes in LiOH (0.2 M). At high current densities the amount of the absorbed hydrogen decreased after its maximum value. In the case of 0.5 Ma/cm$^2$, however, no decrease was observed within the hour measurement (500 hrs.). In $H_2SO_4$(0.1 M), H / Pd reached 0.82 and kept it without decay. The overpotential of Pd in LiOH was measured using RHE and decreased after the maximum. The decrease of the overpotential can give rise to the decrease of the amount of absorbed hydrogen since hydrogen in Pd is closely related with the overpotential.

In order to check the change of the electrode roughness of Pd cathode, we observed the surfaces of Pd cathodes after the electrolysis in LiOH and $H_2SO_4$ by SEM. But no difference was found between them. As a consequence, it is not likely that the enhanced hydrogen absorption in LiOH is caused by the roughening of the surface.

The depth profile of Li of Pd surface after the electrolysis by SIMS is shown. We detected Li in the Pd cathode up to 100 mm in depth. More Li was detected at higher current density. At 500 mA/cm$^2$, more Li diffused into the bulk by longer electrolysis. Li was also detected in the Pd cathode of the 0.5 mA/cm$^2$ electrolysis. The concentration of Li at the surface probably depends on the electrode potential. The electrode potential was about -200 mV vs. RHE at 0.5 mA/cm$^2$, while the redox potential of Li is -3.0 V vs. RHE. Although the LiPD effect could be considered, this gap is so large. Further research is necessary.

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## JAPAN - BLUE WATER LASERS

Thomas V. Prevenslik (Consultant, Tokyo, Japan), "Sonoluminescence, Cold Fusion, and Blue Water Lasers," presented at ICCF4.

AUTHOR'S ABSTRACT

Sonoluminescence (SL) is described as a phenomenon in which the energy in a sound wave becomes highly concentrated so as to generate visible blue light in liquid water at room temperature. Since the wavelength of the sound wave is very large compared to the wavelength of the blue light emitted, SL has been interpreted as a significant focusing of energy. With regard to cold fusion, SL is important because it would offer a significant energy focusing mechanism and offer the prospect of fusing deuterium at room temperature.

However, the blue light observed in SL may be Rayleigh scattered light reflected in the Raman bands of water in a cooperative action with the water behaving in the manner of a chiral liquid crystal. Chiral or twisted helical molecular structures are known to produce blue phases in cholesteric systems when the pitch of the helix is less than about 500 nm. Currently, it is not known if water has a blue phase.

Water is a polar molecule with a high dipole moment and responds to incident light as an oscillating dipole. If a group of water molecules is ordered into a helical structure of an axial extent greater than about the wavelength of blue light and if the individual molecules are oriented so that the dipole moment vector of the molecules is generally pointing in the incident light direction, the group in unison is excited at the frequency of incident light. Hence, SL may be a highly ordered arrangement of water molecules in a liquid crystalline state scattering incident light in the Raman band. However, the sound wave is important. In the expansion, the

molecular order is lost because the intermolecular spacing exceeds the range of electrostatic interaction. However, in compression the water molecules are confined to a spherical geometry and the molecules are ordered into a configuration in resonance with the incident light.

It is an open question whether blue light in phase with the sonic pumping is a cooperative lasing action. The SL lasing action, collectively termed a blue water laser, may amplify the energy of the incident blue light because of the molecular resonance and represent an energy gain in the reflected blue light.

To assess the possibility of a resonant blue phase structure in water, a Molecular Dynamics (MD) simulation of water was performed using the simple point charge (SPC) model comprised of a tetrahedral geometry with the OH distance of 0.1 nm and point charges of qo = -0.8476e on the oxygen position and qh = +0.4238e on each of the hydrogen positions. The tetrahedral angle is 109.4 deg. The Coulomb potential is used between charges. A Lennard-Jones potential is used between oxygen atoms with parameters epsilon = 78.38 and sigma = 0.316 nm. To achieve a MD simulation of water with reasonable computation times and still maintain consistency with a spherical compression, a 1D chain of water molecules was selected. To obtain liquid density at 300 K, the initial configuration consists of about 1400 water molecules in a 0.3 x 0.3 x 400 nm computational box. The chain is free to move in the z-direction and periodic boundary conditions are imposed at the ends. In the x and y directions, the oxygen atom is constrained to the z-axis. The hydrogen atoms are initially placed in a vector pair so that the normal to the H-O-H plane is pointing parallel to the z-axis. The water molecules are free to rotate about the oxygen atom.

The MD simulation temperature was maintained near 300 K. Density was changed by varying the initial spacing between the molecules. The crystal order parameter is computed based on the angular position of the H-O-H normal relative to the z axis. It is found that the water molecules are ordered into a helical geometry for initial molecular spacings less than about 1 nm. The order parameter indicates a molecular rotation of about 80 deg, but the H-O-H normal also rotates around the z-axis as shown in the simplified sketch in Figure 1 [of the paper]. Since the pointing direction coincides with the direction of the dipole moment of the water molecule and the electric vector of the incident light, a resonance condition between the incident blue light and the liquid crystal blue phase of water is predicted. Accordingly, stimulated Raman scattering experiments directed toward a possible energy gain of the blue water laser are recommended to the cold fusion community.
[See also J. Schwinger, "Casimir Light: the Source," Proc. Nat'l. Acad. Sci., USA, March 1993, pp 2105-2106, 6 refs. This paper gives another view on the cause of sonoluminesence. --Ed.]

## JAPAN - COLD FUSION NEUTRONS

Shigeyasu Sakamoto (Dept. Nuc. Eng., Tokai Univ., Kanagawa), "Observations of Cold Fusion Neutrons from Condensed Matter," presented at ICCF4.

AUTHOR'S ABSTRACT

Since the announcements of electro-chemically induced cold fusion, many confirmatory experiments have been conducted throughout the world, however, clear evidences have not been obtained yet.

The present paper concerns the results of our preliminary experiments and apparatus of current experiments. Electrolysis was performed in a small cell, containing 99.8% pure $D_2O$ with NaOH or LiOD. The cathode was a palladium wire of 99% purity with the dimension of 0.1 mm in diameter.

In the early experiment, electrolysis continued being carried out for 19 days at the current density of 140 to 320 $mA/cm^{-2}$ on the palladium cathode. Neutrons were detected by using a thermal neutron detector of $BF_3$ Bonnet counter, 250 mm in length and 25 mm in diameter cylindrical counter filled with 400 mm torr of $BF_3$ gas, with the outer moderator of 5 cm thick paraffin wax.

Results of the experiment indicated a weak evidence for neutron emission from the electrolysis cell. Figure 1 [of the paper] illustrates the time dependence of detected neutrons and Fig. 2 shows frequency distributions of the neutron counting rate for the runs of foreground and background.

After these experiments, we designed and constructed a new measuring system, which is high detection efficiency for neutron, low background and anti-noise for electromagnetic noises. The electrolytic cell was 1cm diameter and 7cm high, polypropilene test-tube with the cathode of palladium wire (0.1 mm in diameter and 20 mm in effective length) and the anode of platinum wire. The arrangement of the cell, $^3$He counter banks and shielding materials are shown in Fig. 3. For the purpose of cross checking, two counter banks were employed. The block diagram of DC current source and measuring system is shown in Fig.4. Neutron detection efficiency, including geometrical acceptance and pulse height discrimination effect, are measured to be 6.4% using a $^{252}$Cf neutron source. The background counting rate of the system was 0.02 cps. This value is equivalent to 0.3 $sec^{-1}$ source neutron.

Experiment on new apparatus started at end of the August. The results of which will be reported in the conference.

## JAPAN - HYDROGEN LOADING

Toshiyuki Sano and Shinji Nezu IMRA Material R&D Co., Ltd., Kariya, Aichi, Japan), "Measurements of Hydrogen Loading Ratio of Pd Electrodes Cathodically Polarized in Aqueous Solutions," presented at ICCF4.

AUTHORS' ABSTRACT

Correlations between deuterium loading ratio and excess heat have been reported by several laboratories. It has been emphasized that achieving high loading is essentially important to give rise to cold fusion reactions triggered by heavy water electrolysis. In this context, we have prepared a series of palladium based alloy electodes with various compositions and processing histories in order to compare

their hydrogen loading ratios to each other. We have demonstrated that loading ratios of Pd-Ag and Pd-Ce alloys decreased with the increase in the Ag and Ce contents, respectively, using a measurement system in which the amount of the evolved hydrogen gas is monitored by a mass flow meter. However, the effect of processing such as swaging and annealing was not clear. The evaluated values varied in the range 0.73 to 0.79 for the various samples ranging from nonannealing to 650°C annealing and from 0% to 98% swage processing ratios. This necessitated a reinvestigation on the dependence of the hydrogen loading ratio on the microstructure of Pd electrodes.

We first checked the accuracy of the mass flow meter used for our previous experiments. It was then found that the linearity of the mass flow meter was not acceptable, in particular at low flow rates where the values were critically influenced. In our previous experiments, three mass flow meters were employed to collect data, using the calibration data supplied by the manufacturer. It was found that the error in calibration could have introduced the above variation of 0.73 to 0.79. It was also found that the pressure drop of the mass flow meter had not been taken into account properly in our previous experiment. The pressure drops associated with mass flow meters bring dead volume which leads to an apparent hydrogen uptake. Therefore, the dead volume must be determined to be subtracted by carrying out a control experiment with a Pt electrode. Although this was considered in our previous experiments and the pressure drops were small (5 mm $H_2O$ at a typical operating flow rate), the control of the electrolytes levels was not adequate, causing variation in dead volume.

To solve the above problems we decided to use gas burettes as well as mass flow meters. In this current study, the following samples were prepared to evaluate their hydrogen (deuterium) loading ratios: 1) Pd-Rh alloy rods, 2) Swaged pure Pd rods with various processing ratios (0 - 99.8%), 3) Swaged pure Pd rods followed by annealing at various temperatures (350 - 1200°C).

The relationship between the H(D)/Pd and processing histories will be discussed. Some of the above samples were subjected to cracking during the electrolysis in the measurement of the hydrogen loading ratios. The effect of cracking on hydrogen loading will also be discussed.

## JAPAN - N'S FROM PIEZOELECTRIC CRYSTALS

Toshiaki Shirakawa (Dept. Soc. Info. Proc., Otsuma Women's Univ., Tokyo), Masatoshi Fujii, Masami Chiba, Keisuke Sueki, Takeshi Ikebe, Shinosuke Yamaoka, Hiroaki Miura, Toshihiro Watanabe, Tachishige Hirose, Hiromichi Nakahara (Fac. of Sci., Tokyo Metro. Univ., Tokyo), and Michiaki Utsumi (Fac. of Eng., Tokai Univ., Kanagawa, Japan), "Particle Acceleration and Neutron Emission in a Fracture Process of a Piezoelectric Material," presented at ICCF4.

AUTHORS' ABSTRACT

In a solid crushing process, chemical bonds are broken and ionic charges appear on the crushing surface. An active state is induced by these charges. The miocene-chemical reaction raises extraordinary chemical reactions. Kluev et al. and Derjaguin et al. have reported neutron emissions from deuterated metal due to the miocene-chemical process. Also in a crushing process of piezoelectric materials, a high voltage generates between a cleavage in piezoelectric crystal that impacted in the crushing process. Deuterium atom ionize and accelerate by this high voltage. Accelerating deuterium ion collide with another deuterium atoms. With the collision of accelerated deuterium atoms occurs fusion reaction and emit neutrons. In the previous paper, we reported a neutron emission of a crushing process of lithium niobate-deuterium system. This nuclear reaction is the so-called miocene-fusion. To make sure that this result was not mechanical noise effects, we examined a comparison of the neutron emission of deuterium and hydrogen atmosphere gases in a crushing process of lithium niobate.

We chose a single crystal of lithium niobate($LiNbO_3$) as the piezoelectric material. It has a high piezoelectric strain constant of $6.92 \times 10^{-11}$ C/N($d_{15}$) and a relatively low dielectric constant of 85.2($X_{11}{}^{T}$). The generated voltage by forcing on the piezoelectric material is proportional to the piezoelectric strain constant and inversely proportional to the dielectric constant. A high piezoelectric constant and low dielectric constant are necessary to generate high voltage. The low conductivity ensures the charge is retained after the charge unbalance of the fracturing process.

The vibromill (VP-100, ITOH Co. Ltd.) was composed of a 93 $cm^3$ cup and a stainless steel ball (40 mm dia.) which vibrated at the frequency of 50 Hz with the vertical amplitude of 3 mm. The emitted neutrons were detected using 8 $^3He$ proportional counters arrayed circularly in a cylindrical shaped paraffin block of 38 cm outer diameter and 10 cm inner diameter. The neutrons thermalized by the paraffin and reacted with $^3He$ making a proton and a tritium with a Q value of 760 keV. The pulse heights of output signals of the $^3He$ counters were digitized by analog to digital converters. The vibromill was set in the center of the cylindrical paraffin. In order to increase the signal to noise ratio, counts between 600 and 1599 channels were selected. The detection efficiency was measured to be 2.0% by a calibrated $^{252}Cf$ source. The experiment was done in the low background facility at Nokogiri mountain, belonging to the Cosmic-ray Research Inst., Univ. of Tokyo. It was located underground at the depth of 100 m water equivalent. The average count rate of the background neutrons were observed 5.7 counts /h during 960 hrs.

The crushing for a sample was continued for 1 hour duration. The crystal of lithium niobate was ~ 3 mm granule initially and after 15 minutes of crushing the size was reduced to ~ 1 μm diameter. The crushing process of $D_2$+$LiNbO_3$, $H_2$+$LiNbO_3$ were carried out alternatively. A graph shows the observed neutrons of mean value of 1 hour with error bar from background, hydrogen and deuterium gases in the crushing of lithium niobate. The trial number of experiments of $D_2$+$LiNbO_3$, $H_2$+$LiNbO_3$ and background were 24.6, 10 and 960 respectively. The counts of observed average neutrons

$D_2$+$LiNbO_3$ , $H_2$+$LiNbO_3$ and background during 1 hour were 6.4 ± 0.5, 5.7 ± 0.7, and 5.7 ± 0.08 respectively.

We observed excess neutrons emission over the background neutrons in the crushing process of $D_2$+$LiNbO_3$ system. On the other hand, in the H2+$LiNbO_3$ system, we did not observe excess neutrons emission over background neutrons. We also analyzed by a statistical treatment of the observed data. The comparison of statistical difference between $D_2$+$LiNbO_3$ and back ground emitted neutron counts were regarded as 92.2% significant. In contrast the difference of $H_2$+$LiNbO_3$ and background observed neutron counts were not regarded as 99.9% significant. These results given that excess neutrons were emitted in the crushing process of $D_2$+$LiNbO_3$, but excess neutrons were not emitted in the crushing process of $H_2$+$LiNbO_3$. The mechanical noise did not disturb the experimental results.

We concluded that excess neutrons were emitted from the crushing process of $D_2$+$LiNbO_3$. The excess neutrons were not observed in the crushing process of $H_2$+$LiNbO_3$. These results are given as proof that mechanofusion occurred in crushing process of $D_2$+$LiNbO_3$.

## JAPAN - MULTI-BODY FUSION

Akito Takahashi (Dept. of Nuc. Eng., Osaka Univ., Osaka, Japan), "Some Considerations on Multibody-fusion in Metal-deuterides," presented at ICCF4.

AUTHOR'S ABSTRACT

To explain anomalous effects of large (0.1 to 5 kev/atom level) excess heat, He-4 generation, emission of high energy charged particles, very low level emission of neutrons with two-components spectrum and very small n/T ratio, a competing process of d+d, d+d+d and d+d+d+d in metal-deuterides has been hypothesized. To add some plausible conditions to this model, some considerations on the transient dynamics of microscopic deuteron clustering and the decay-channels of virtual compound nucleus are given in this paper.

Cold nuclear fusion rate in solid is approximately given as (deuteron number density) x (pair or cluster formation probability) x (barrier penetration probability) x (internuclear formation rate of virtual compound nucleus). Maximum, if possible, fusion rate is therefore given as (deuteron number density) x (internuclear formation rate of virtual compound nucleus), which is approximated as NvS/E where N is the deuteron number density, v the velocity and S/E the internuclear cross section with the astrophysical S-factor S. Maximum d+d fusion rate at room temperature is then estimated as about $10^{10}$ f/s/cc which is equivalent to 0.01 w/cc. Therefore, it is very difficult to explain observed excess heat level of 0.01 to 4 kw/cc, by the d+d fusion processes. Anomalous enhancement of strong interaction is required to overcome this difficulty. If d+d+d and d+d+d+d fusions take place in solid, we can expect a $10^6$ to $10^{11}$ times magnification of S-factors; we have then to seek feasible conditions in transient of metal-deuteride for meaningful enhancements of cluster formation probabilities and barrier penetration probabilities. In addition, we have to study possible decay channels of virtual compound nuclei ($^4He^*$, $^6Li^*$ and $^8Be^*$) resulting emission of particles (α, p, t, n, γ etc.) with specified kinetic energy releases.

To enhance the barrier penetration probabilities to a meaningful level (greater than $10^{-10}$ for d+d reaction, greater than $10^{-21}$ for d+d+d+d reaction), the mutual Coulomb repulsive potential must be very much screened with the transient motion of quasi-free electrons (e.g., 4d electrons of Pd) to result in the equivalent relative energy E greater than about 40 eV. Preparata suggested that "deep holes" with about 100 eV depth formed in transient at tetrahedral sites of $PdD_X$ (X>l.0) by the QED plasma oscillation. The author is conceiving an image of transient dynamics, as shown in Fig. 1, where the nearest deuteron cluster would be formed around the time = t2 at tetrahedral sites when deuterons at t- and o-sites are excited to higher harmonic oscillators at time = t0. Very

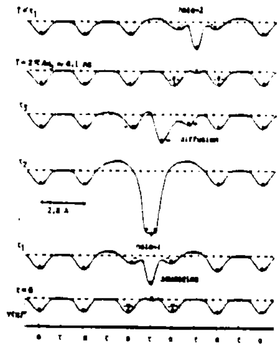

Fig.1: Image of dynamic process for cluster formation

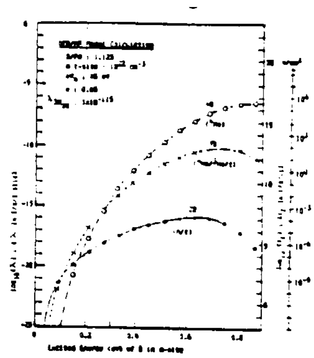

Fig.2: Fusion rates in PdDx

approximated calculations for the cluster formation probabilities and barrier penetration probabilities in this process were done to obtain fusion rates of competing 2D, 3D and 4D reactions, as shown in Fig. 2.

Concerning outgoing channels of the virtual compound nuclei, the electromagnetic interaction with the QED plasma oscillation is interested. Average propagation speed of QED photons in the lattice is 3xlO$^{-18}$ sec/nm. The virtual compound nucleus $^4He^*$(23.8MeV;Iπ) by d+d fusion should have a very short life time $10^{-21}$ sec, for spin-parity Iπ of either S-wave or P-wave state, to decay to known (n + $^3He$) and (p + T) channels, and no transition to $^4He$(g.s.:0+) with the 23.8 MeV excited energy transfer by QED photons to the plasmon oscillation is possible. However, for $^6Li^*$(25.32MeV:Iπ) and $^8Be^*$(47.7MeV:Iπ) of virtual compound nuclei by 3D and 4D fusions, excited energy transfer by QED photons may happen if spin-parity is 4- for $^6Li^*$ and 3- or 5- for $^8Be^*$ (namely P-wave states).

For example, outgoing channel of $^8Be^*$(47.7MeV:5-) can be at first step; $^8Be^*$(25.5MeV:4+) + QED photons (22.2MeV in sum), and at second step; $^8Be^*$(25.5MeV:4+) breaks up to α(l2.8MeV) + α(12.8MeV). High energy α-particles (He-4) and large excess heat might be generated by this process.

## JAPAN - CHARGED PARTICLE SPECTRA

Ryoichi Taniguchi (Res. Inst. for Adv. Sci. & Tech., Univ. of Osaka, Osaka), "Characteristic Peak Structures on Charged Particle Spectra During Electrolysis Experiment," presented at ICCF4.

AUTHOR'S ABSTRACT

Origins of strange peak structures, which appeared frequently on charged particle spectra during electrolysis experiments, were studied. The charged particles were detected by a Si-SSD attached close to the thin-foil palladium cathode which formed the bottom of an electrolysis cell.

An example is shown of the charged particle spectrum during $D_2O$ electrolysis. Weak peaks were distributed in the energy region from 2 MeV to 10 MeV, and did not correspond to the peak patterns of the Radon and Thoron. Two categories of peaks could be interpreted as the unexpected responses of the background radiations. One was an effect that the high energy particles penetrated the detection layer of the Si-SSD. The other was giant electric-dipole resonance reactions,($\gamma$7,p),($\gamma$,$\alpha$) of Si and the elements surrounding the detector. Other structures, however, were remained completely unexplained.

The spectrum pattern seemed to have some correlation with experimental conditions, i.e., electrolysis, electrolyte, and materials surrounding the detector. The counting rate of the "strange peak region" (4-10 MeV) during $D_2O$ and $H_2O$ electrolysis was remarkably higher compared with that of background runs. These phenomena could not be explained by the ordinary D-D reaction occurring in the palladium cathode. An accurate determination of the peak energies of the strange structures would be a key to resolve the unknown nuclear reaction lying behind the anomalous phenomena.

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**RUSSIA - NUCLEAR ORIGIN OF HEAT**

Yan Kucherov, Alexander Karabut and Irina Savvatimova (Sci. Indust. Assoc. "Luch", Podolsk / ENECO, Utah), "Heat Release and Product Yield of Nuclear Reactions in Pd - D System," presented at ICCF4.

AUTHORS' ABSTRACT

On the basis of experimental results obtained in the past few years, an attempt to explain discrepancies in various publications is made. Up to this time there were several publications on inconsistent excessive heat production in relation to nuclear products measurements, so the question of nuclear origin of this heat is still open.

If we assume nuclear nature of "cold fusion", we must account for $10^{12}$- $10^{14}$ nuclear particles per second with MeV-range energy or $10^{15}$- $10^{17}$ particles with KeV-range energy to explain the detectable amount of heat. Since most experiments use deuterium and regular nuclear detection, it is easy to predict what should not be produced with this effect. High deuterium concentration media must produce significant amount of neutrons if deuterons are accelerated to energies more than 10 KeV. That eliminates charged particles with $Z \leq 2$ as high energy end-products of the effect. Gamma-quanta also cannot be produced because they are too easy to detect. At the high energy end, the only particles left are heavy ones ($Z \geq 2$ ) and exotic ones like neutrinos, which are difficult to detect.

On the low energy end, almost anything except neutrons is difficult to detect. So far the only product measured in remotely close to expected quantities to the heat released is X-rays ($10^9 s^{-1}$). Taking into account X-ray adsorption in palladium and even distribution of reaction with depth, it is four or five orders short of that needed to explain heat. That brings down the possible amount of high energy electrons, because of the long path of these electrons and effective bremsstrahlung. That brings most of the possible X-rays in energy range lower than 10 KeV, where detection capabilities are small.

Use of d-d reaction neutrons and X-rays as indicators leaves us with limited options on nuclear products characteristics: low energy products or heavy products. The current database for low energy products is too thin to make conclusions on the nature of new nuclear effect. Some conclusions may be made on the type of reactions that produce heavy particles. If we put aside the problem of Coulomb barrier, we come out with low - Z elements fission or combination of fusion - fission. This approach solves the problem of nuclear ashes. Calculations based on conservation laws (conservation of momentum, energy, spin, isospin, parity) assuming that most of the reaction products are formed in a ground state due to low radioactivity of resulting products, show that He, Li, B, C, N, F, Ne, Mg, Si, S, Ar, Ca, Ti, Cr, Fe, Ni, Zn, Ge, Se, Sr, Zr, Mo, Ru can be fission products for palladium. Most of these elements are the natural impurities in metals in ppm range and some of them are present in the experimental environment and therefore are difficult to detect, but 1ppm accounts for ~ 10KJ of energy and such a possibility cannot be ignored.

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## D. MEETINGS AND MISCELLANEOUS

**MINSK COLD FUSION CONFERENCE - MAY 1994 AMENDED CALL FOR PAPERS**

A bilingual, international conference on cold nuclear fusion and affiliated energy systems will be held in Minsk, Republic of Belarus during the last week of May, 1994. Papers accepted will be published in English and Russian editions of proceedings that will be provided to attendees at the start of the conference. Presentations of the papers can then concentrate on the latest developments and the answering of questions. The proceedings are expected to provide a tutorial overview of the new science of cold nuclear fusion for a multi-disciplinary audience and provide the latest experimental and theoretical findings.

Russian language papers should be sent to:
Dr. Filimonov V.A.
14 Leningrad St., Research Inst. of
Physical and Chemical Problems
Minsk - 80, 220080
Belarus.

Papers in English may be submitted to Hal Fox, P.O. Box 58639, Salt Lake City, UT 84158. Notification of acceptance will be sent by Jan. 15, 1994. Papers must be received by Feb. 31, 1994.

$250 Conference attendance includes room and meals. Authors of accepted papers must include the check for the conference when submitting the paper. Page costs for pages in excess of 6 (including figures) will be $100 per page. A total of about 70 papers will be selected and published in the proceedings. Translation costs, if handled by the organizing committee staff, will be $20 per page. Authors are urged to submit their papers in both English and Russian. Words on figures may be in English.




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