Nuclear Processes in Trapped Neutron Catalyzed Model for Cold Fusion

Hideo Kozima and Seiji Watanabe
Department of Physics
Shizuoka University, Japan

Abstract

Results are given of detailed calculations for 1) the probability of channeling for particles generated in n-d and n-p fusion reactions, 2) the fusion probability of a triton generated in n-d fusion with a deuteron, and 3) the fusion probability of a deuteron accelerated by n-d elastic collision with another deuteron. Many neutrons are generated in successive reactions of d-d fusion reactions triggered by trapped thermal neutrons, sufficient to explain experimentally observed anomalous excess heat, neutron bursts, and tritium anomalies in optimum situations. The results confirm preliminary estimations used in the previous works.

1. Introduction

The cold fusion phenomenon has been observed in various materials. These materials are divided into two categories: (1) materials containing mainly a lot of deuterium (let us call them "deuterides" hereafter); and (2) materials containing mainly a lot of hydrogen ("hydrides").

We had proposed a model (Trapped Neutron Catalyzed Model for Cold Fusion, TNCF model) [1–4] to explain cold fusion phenomenon and the model gives a consistent qualitative understanding of experimental facts in the phenomenon, even if not quantitative.

The reactions having connection with the model are as follows:

$$n + p = d\,(1.33\ \text{keV}) + \gamma\,(2.22\ \text{MeV}) \quad (1)$$

$$n + d = t\,(6.98\ \text{keV}) + \gamma\,(6.25\ \text{MeV}) \quad (2)$$

$$p + d = {}^{3}\text{He}\,(5.35\ \text{keV}) + \gamma\,(5.49\ \text{MeV}) \quad (3)$$

$$d + d = {}^{3}\text{He}\,(0.82\ \text{MeV}) + n\,(2.45\ \text{MeV}) \quad (4)$$

$$= t\ (1.01\ MeV) + p\ (3.02\ MeV) \quad (5)$$

$$= {}^4He\ (76.0\ keV) + \gamma\ (23.8\ MeV) \quad (6)$$

$$t + d = {}^4He\ (3.5\ MeV) + n\ (14.1\ MeV) \quad (7)$$

$$d + {}^3He = p\ (14.68\ MeV) + \alpha\ (3.67\ MeV) \quad (8)$$

Here, it is useful to give attention to the difference in fusion cross sections of reactions (1) and (2). The cross sections of these reactions depend on the energy E of the thermal neutron and increase as $E^{-1/2}$ with decrease of the energy. This fact means low temperature is advantageous to realize cold fusion for the same density of trapped thermal neutrons. The fusion cross section of reaction (1) for a neutron with energy of 25 MeV is about 3×10^{-1} barns and that of reaction (2) for the same energy is about 6×10^{-3} barns [5]. So a thermal neutron fuses more easily with a proton than with a deuteron by a factor of 50.

Some characteristics of the cold fusion phenomenon in deuterides and hydrides are pointed out as follows.

(1) Cold fusion in deuterides

Table 1.
Attenuation lengths l_{eff} of 6.25 MeV (in Ti and Pd) and 2.22 MeV (in Ni) photons in metals

metal	Ti	Ni	Pd
l_{eff} (cm)	8.0	3.4	2.2

Once reaction (2) occurs in deuterides between a trapped thermal neutron and a deuteron in the sample, the generated triton and photon will give several effects on the sample. The attenuation lengths of 6.25 MeV and 2.22 MeV photons in relevant metals are given in table 1.

If the sample is large enough to attenuate the photon (2 cm for Pd metal), the sample will be heated drastically as observed by rare experiment [6]. In samples with smaller linear dimensions, excess heat will result from other particles generated in reactions induced by the triton. In the Ti/D system, however, the attenuation length is too long (~8 cm) to heat the usually used samples drastically and no remarkable excess heat has been observed hitherto.

The triton generated in reaction (2) will be observed in the remains as tritium [7, 8]. In an optimum situation, the triton will have a fusion reaction with a deuteron in the sample to generate ^4He and a high-energy neutron with an energy of 14.1 MeV according to reaction (7). ^4He generated in this reaction will be observed as a helium atom [9, 10] or as an alpha particle.

The high-energy neutron will have two effects: the neutron itself will be observed coming out from the sample [11, 12], or the neutron will make predominantly elastic collisions with deuterons in the sample. A deuteron accelerated by an elastic collision with the neutron will obtain enough energy to fuse with another deuteron in the sample by reactions (4) or (5) (detailed calculation will be given later).

When the neutron generated in reaction (7) loses almost all its energy by elastic collisions with deuterons, it contributes to reaction (2) together with the neutron generated in reaction (4). In an optimum situation where reactions (2), (7), and (4) occur successively (a chain reaction), many neutrons will be generated [13] and a neutron burst will be observed [7, 8, 14] (detailed calculation will be given later).

(2) Cold fusion in hydrides [4]

Once reaction (1) occurs in hydrides, a deuteron and a photon are generated. The generated photon can effectively heat a sample with enough dimension to attenuate the photon [15]. The deuteron also contributes to the heat of the sample, losing its energy by elastic collisions with charged particles in the sample. The deuteron can fuse by reaction (3) to generate ^3He which will contribute to heat the sample and also be measured in hydrides.

The larger cross section of reaction (1) compared with that of reaction (2) is favorable for stationary heat generation for hydrides. It is possible to say that we will obtain excess heat generation linearly depending on the number of trapped thermal neutrons in a sample. This prediction should be checked experimentally.

On the other hand, the successive reactions feasible in deuterides are absent in hydrides. It is possible to conclude that there are neither neutron bursts nor explosive excess heat generation in hydrides by the TNCF mechanism.

(3) Direct evidence for the effect of thermal neutrons in cold fusion

Recent private communication [16] reported an interesting observation in a KD_2PO_4 single crystal. When background neutrons were increased artificially to 100 times the natural background, the enhancement factor (number of neutrons in the transition region/number in others) increased from 4 to 25. This result shows that the effect of thermal neutrons is nonlinear to its density suggesting a productive effect (chain reactions).

Similar effects of thermal neutrons

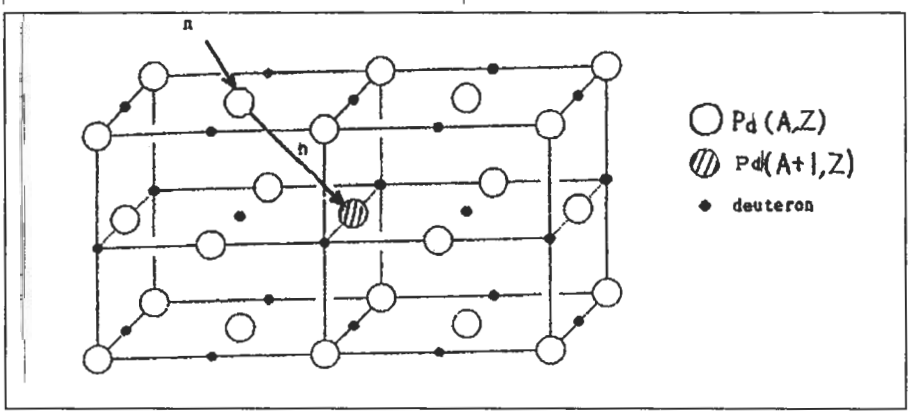

Figure 1. Momentum change of the nucleus in the emission and absorption of a neutron.

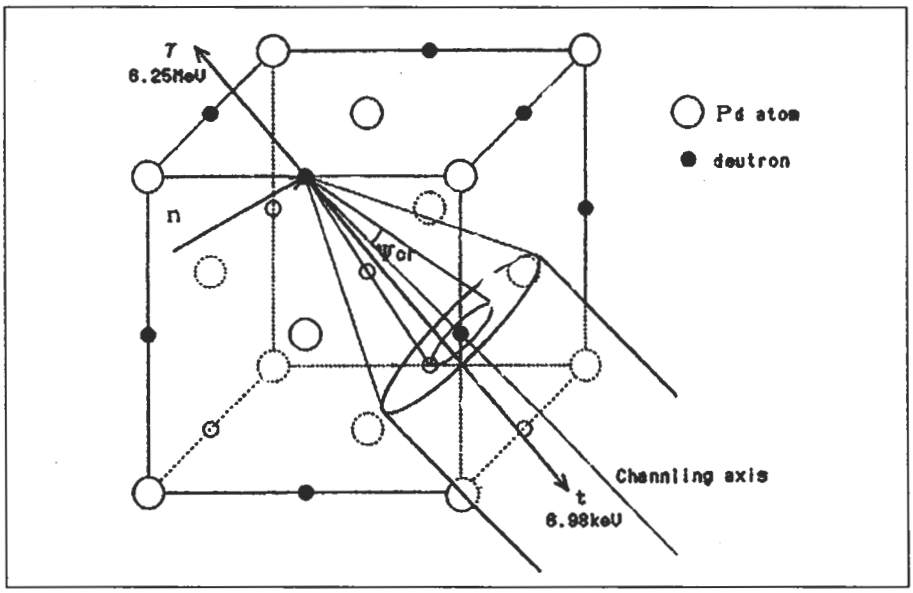

Figure 2. A channeling axis.

have been investigated several times up to now. The first one was done in 1989 [17]. Others were done afterwards with much care [12, 18].

Inexistent results of the cold fusion phenomenon [19] were also obtained including the Kamiokande experiment in 1992 (in Japan) showing that there is no cold fusion without background neutrons.

These data clearly support the TNCF model directly.

(4) Irreproducibility

Irreproducibility of cold fusion phenomenon (especially gigantic excess heat, neutron bursts, and tritium anomalies), the remarkable controversial problem throwing a big question to all scientists, had been explained in the TNCF model as a result of stochastic processes working in samples to realize the optimum conditions to make cold fusion feasible (trapping of thermal neutrons, realization of chain reactions, etc.).

The direct support from experiments with controlled thermal neutrons [12, 16, 18], and the self-consistent interpretation of all experimental results except the absence of high-energy photons, shows that something is true in the TNCF model. The question about the absence of the high-energy (6.25 and 2.22 MeV) photons might be related to the fact that the absorption coefficient of a photon in many materials has a minimum at a range from 1 to 10 MeV of the photon energy. The critical review of experimental data by E. Storms [20] is useful to overview the whole range of the cold fusion phenomenon.

We will give some detailed calculations about nuclear processes in the TNCF model in this paper.

2. Neutron Mössbauer Effect

Among the mechanisms responsible for neutron trapping, the neutron Mössbauer effect is the one concerned with individual nucleus. As explained in a previous paper [3], a nucleus with a mass number A and even atomic number Z around 26 in a crystal lattice is responsible for the neutron Mössbauer effect, which works as a mechanism to confine neutrons effectively in the lattice (M-mechanism). The neutron trapped by this mechanism is free from the short lifetime (about 900 seconds) of the isolated neutron.

The momentum change of the nucleus in the emission and absorption of a neutron is pertinent to the lattice, while the difference between energy levels in the nucleus with $(A + 1)$ and Z is pertinent to energy levels in the nucleus (fig. 1).

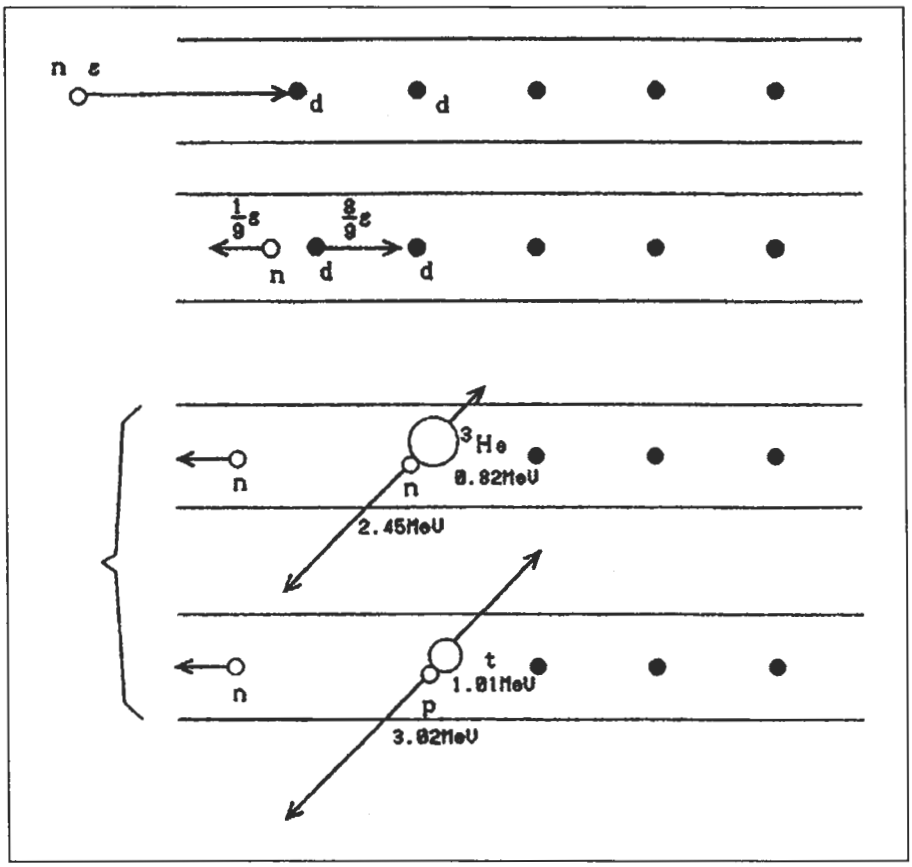

Figure 3. Reactions with a trapped neutron in a channeled axis.

A neutron with an energy 5.33 eV has the same momentum as that of a photon with energy 100 keV which corresponds to photons usually used in the Mössbauer resonance technique. Thus, ordinary crystal can give rise to the neutron Mössbauer effect for neutrons with energies less than 100 keV, including the thermal energy (0.025 eV). The neutron Mössbauer effect is legitimized by analogy with the photon Mössbauer effect.

This mechanism of neutron trapping depends on the dynamic character of the local lattice around the pertaining nucleus. In an inhomogeneous material where cold fusion occurs, the dynamical characteristics of the lattice vary place to place. To keep the M-mechanism effective, the size of the locally homogeneous region should have a minimum value. On the other hand, to have a long trapping time T of the neutron in the material, it is desirable to make the total volume of the locally homogeneous region as large as possible.

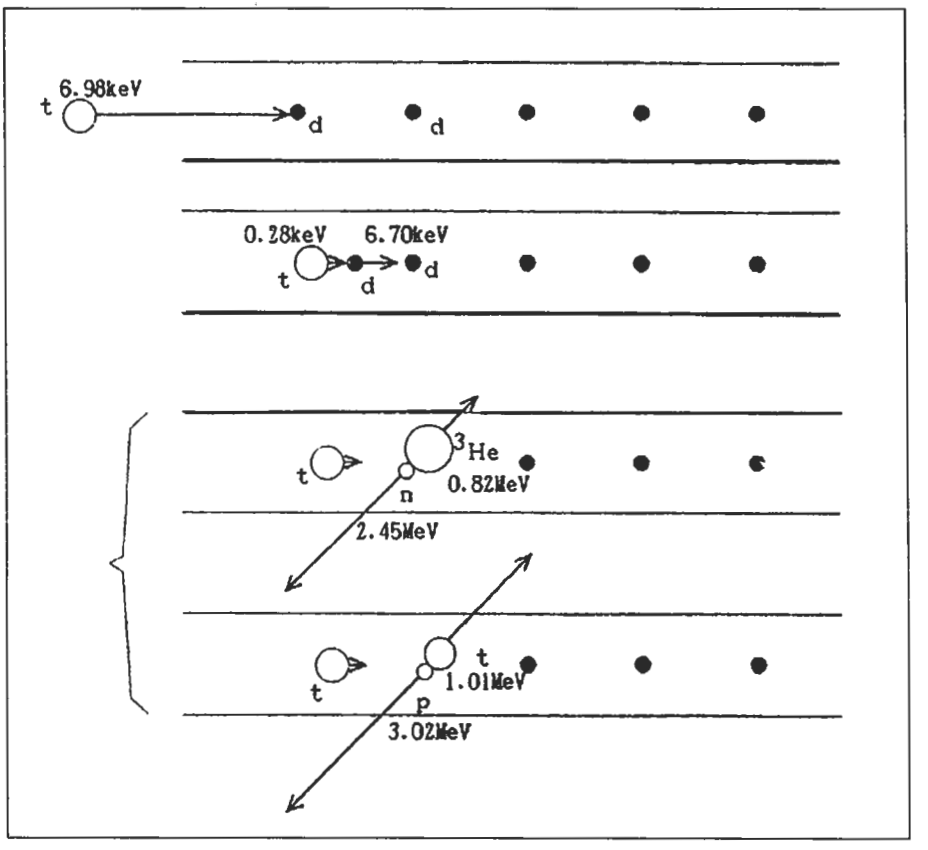

Figure 4. Further reactions in a channeled axis.

3. Channeling

There is propagation of a neutral or a charged particle through crystal without energy loss, i.e., channeling [21, 22]. Channeling occurs when the de Broglie wavelength of the particle is short compared with the lattice constant of the crystal and the propagation vector makes a small angle with a crystal axis or a crystal plane [22]. In our case, it occurs when the propagation is around a specific crystal direction (ohsline) through interstitial sites (a channeling axis; an example is shown in fig. 2).

Once a thermal neutron makes a fusion reaction with a deuteron or a proton in a material occluding it, particles generated in the reaction have appropriate energies to channel through the material where the crystal lattice is ideal. High-energy tritons or deuterons generated in reactions (2) or (1) make collision effectively with deuterons or protons to fuse with them, shown as follows.

A charged particle can propagate through a channel with a radius r_0 when the angle ψ between its momentum and a channel axis is smaller than a critical angle ψ_{cr}. The ψ_{cr} for a particle with an energy E and a charge $Z_1 e$ through a lattice composed of atoms with nuclear charge $Z_2 e$ is given by following formulae:

$$\psi_{cr,1} = [(2Z_1 Z_2 e^2)/(Ed)]^{1/2}, \ (E < E'), \qquad (9)$$

$$\psi_{cr,2} = [(Ca_{TF}\psi_{CR,1})/(2^{1/2}d)]^{1/2}, \ (E > E'), \qquad (10)$$

where $E' = 2Z_1 Z_2 e^2 d/a_{TF}^2$, $C \simeq 3^{1/2}$ and the Thomas-Fermi atomic radius a_{TF} for this case is given by

$$a_{TF} = 0.8853 a_0 (Z_1^{1/2} + Z_2^{1/2})^{-2/3}.$$

The parameter d in the above formulae is a distance of matrix atoms along the channel axis.

For the triton with an energy of 6.98 keV, $E/E' < 1$ and $\psi_{cr,2} = 0.105$ rad. A triton which is generated by reaction (2) can propagate along one of twelve main channels through the site where there was a deuteron with a probability of 3.3%. On the other hand, the deuteron which is generated by reaction (1) can propagate along one of twelve main channels with a probability of 7.6% according to similar estimations (fig. 2). Those probabilities increase with the decrease of particle energy.

Now, we proceed to individual reactions between particles.

4. Tritium Production Rate in Deuterides

As explained in section 1 and well known in neutron physics [1,5], the fusion cross section of a neutron with a deuteron increases rapidly with the decrease of the impinging neutron energy ε, while the elastic scattering cross section remains constant at about 3.2 barns under $\varepsilon = 1$ MeV. The ratio of the two cross sections is about 10^{-6} at $\varepsilon = 10^6$ eV and is 10^{-3} at $\varepsilon = 10^{-3}$ eV.

To interpret rare experimental results of observed tritium anomalies, we must be aware of the fact that detection of neutrons and tritium are

usually not simultaneous. So, we may assume in this case that one or another trapping mechanism is very effective and many neutrons are trapped in the sample. Then the fusion reaction (2) will occur to produce a lot of tritons which will make effective collisions to accelerate deuterons when propagating along an OHS line, or to lose energy by the coulomb interaction with charged particles in the lattice and to remain in the sample.

By the head-on elastic collision of a triton with a static deuteron, the triton loses 12/25 of its initial energy. The accelerated deuteron makes a collision with another deuteron. If a deuteron with an energy of $(12/25) \times 6.98 = 3.35$ keV propagates along an OHS line in a cylinder with a cross section πr_0^2, it induces about two d-d fusions in 10^{-4} seconds with occluded deuterons generating one triton by the reaction (5) in an infinite sample [2] in an optimum situation, where r_0 is the radius of the channel. At the same time, the deuteron generates one neutron by reaction (4). Considering the average fusion length of about 8×10^3 cm, we obtain 10^4 neutrons per second in a sample with a size $1 \times 1 \times 1$ cm^3 with 8000 reactions of reaction (4) per second (fig. 3).

This mechanism results in two effects: 1) when the trapping mechanisms work effectively for higher energy neutrons in a sample with enough inhomogeneity, the neutrons lose energy effectively and are trapped as warm or cold neutrons to fuse with deuterons according to reaction (2) and many tritons are generated; and 2) when the trapping mechanisms for higher energy neutrons don't work well, the 2.45 MeV neutrons propagate along an OHS line to make a sequential neutron-breeding process generating many observed neutrons (as discussed in the next section).

In some experiments [7, 23, 24] the first mechanism would be predominant and tritium is generated by a chain reaction of reactions (4) and (5) interposed by t-d, n-d and d-d elastic collisions. In one experiment [23], a part of the neutron burst preceding the tritium emission would be stored effectively as trapped neutrons in the sample. After a neutron burst, the sample becomes the second type by effects of the fusion products including heat and the trapped neutron could work to initiate the chain reaction generating a lot of tritium to give t/n ~ 10^8. In another experiment [24], there was no neutron burst above background and the trapped neutrons would be the initiator of the chain reaction that generates many tritons on the order of t/n ~ 10^4.

5. Neutron Breeding Rate

The neutron breeding rate is calculated starting from one neutron with an energy 2.45 MeV (or 14.1 MeV) emitted along a OHS line (channeling direction). The neutron makes collisions with deuterons on the line and the recoiled deuterons generate five (or six) neutrons by reaction (4) in 10^{-6} seconds in an infinite sample (fig. 4). In this calculation, simplifications were made assuming 1) the particles always propagate on an OHS line, and 2) an amount of energy transferred by elastic collisions is that of the average with the rigid spheres collision model.

It is also assumed arbitrarily that one out of five (or six) neutrons with energy 2.45 MeV generated in reaction (4) is possible to start another propagation along an OHS line to produce five (or six) neutrons again to continue the reaction forever. In this optimum situation, one n-d reaction generates neutrons about 10^6 per second and the neutrons are emitted from the sample if the trapping of high-energy neutrons is not effective. This story only occurs in an optimum situation achieved very rarely in samples and corresponds to very rare, irreproducible events giving experimental results with neutron bursts [9, 14].

6. Conclusion

It is difficult to prove the occurrence of the cold fusion phenomenon in materials from the first principles because the physics of it includes statistical properties. The estimations given above illustrate a possibility of the occurrence of the cold fusion phenomenon in the presence of abundant thermal neutrons in materials pertinent to the phenomenon, and the possibility of the existence of many neutrons in appropriate materials has been shown in the preceding papers [1–4]. The photon with energy of 6.25 MeV (or 2.22 MeV) has been rarely measured [25] and should be a target of future enthusiastic experiments. CF

References

1. H. Kozima. Trapped Neutron Catalyzed Fusion of Deuterons and Protons in Inhomogeneous Solids. Proceedings of ICCF 4, p. 5–1, Electric Power Research Institute, California, USA, (1994); and Trans. Fusion Tech. 26, 508 (1994). And also: Trapped Neutron Catalyzed Model for Cold Fusion. *Cold Fusion Source Book*, EPRI, Salt Lake city, Utah, USA (to be published).
2. H. Kozima and S. Watanabe. t-d and d-d Collision Probability in the Trapped Neutron Catalyzed Model of the Cold Fusion. *Proceedings of International Symposium Cold Fusion and Advanced Energy Sources* (May 24-26, 1994, Minsk, Belarus) (in Russian), p. 299.
3. H. Kozima. Neutron Mossbauer Effect and the Cold Fusion in Inhomogeneous Materials. *Nuovo Cimento* 27A, 1781 (1994).
4. H. Kozima. On the Cold Fusion in Ni-H System. *"Cold Fusion"* 8, 5 (1995).
5. T. Nakagawa, T. Asami and T. Yoshida. Curves and Tables of Neutron Cross Sections. *JAERI-M 90-099, NEANDC(J)-153/U INOC(JPN)-140/L* (July, 1990).
6. M. Fleischmann and S. Pons. Electrochemically induced Nuclear Fusion of Deuterium. *J. Electroanal. Chem.* 261, 301 (1989).
7. R.K. Rout, M. Srinivasan, S. Shyam and V. Chitra. Detection of High Tritium Activity on the Central Titanium Electrode. *Fusion Tech.* 19, 391 (1991).
8. T.N. Claytor, D.G. Tuggle and S.F. Taylor. Evolution of Tritium from Deuterided Palladium Subject to High Electrical Currents. *Frontiers of Cold Fusion*, p. 217, ed. H. Ikegami, Universal Academy Press (Tokyo) (1993); S.F. Taylor, T.N. Claytor, D.G. Tuggle and S.E. Jones. Search for Neutrons from Deuterated Palladium Subject to High Electric Currents. *Proc. Fourth Intern. Conf. on Cold Fusion*, Lahaina, Maui, Dec. 6–9, 1993, Vol. 3, p. 17, EPRI TR-104188.
9. E. Yamaguchi and T. Nishioka. Direct Evidence for Nuclear Fusion Reactions in Deuterated Palladium. *Frontiers of Cold Fusion*, p. 179, ed. H. Ikegami, Universal Academy Press (Tokyo) (1993).
10. M. H. Miles and B. F. Bush. Heat and Helium Measurements in Deuterated Palladium. *Trans. Fusion Tech.* 26, 156 (1994).
11. A. De Ninno, A. Frattolillo, G. Lollobattista, G. Martinio, M. Martone, M. Mori, S. Podda and F. Scaramuzzi. Evidence of Emission of Neutrons from a Titanium-Deuterium System. *Europhys. Lett.* 9, 221 (1989).
12. S. Stella, M. Corradi, F. Ferrarotto, V. Milone, F. Celani and A. Spallone. Evidence for Stimulated Emission of Neutrons in Deuterated Palladium. *Frontiers of Cold Fusion*, p. 437, ed. H. Ikegami, Universal Academy Press (Tokyo) (1993).
13. S .E. Jones, E.P. Palmer, J.B. Czirr, D.L. Decker, G.L. Jensen, J.M. Thorne, and S.E. Tayler. Observation of Cold Nuclear Fusion in Condensed Matter. *Nature* 338, 737 (1989).
14. E. Yamaguchi and T. Nishioka. Cold Nuclear Fusion induced by Controlled Out-Diffusion of Deuterons in Palladium. *Jpn. J. Appl. Phys.* 29, L666 (1992).
15. S. Focardi, R. Habel and F. Piontelli. Anomalous Heat Production in Ni-H System. *Nuovo Cimento* 107A, 163 (1994).
16. A. Lipson et al. A New Cold Fusion Phenomenon?

(Report by V. A. Filimonov) *"Cold Fusion"* 7, 24 (1995).
17. G. Shani, C. Cohen, A. Grayevsky and S. Brokman. Evidence for a Background Neutron enhanced Fusion in Deuterium absorbed Palladium. *Solid State Comm.* 72, 53 (1989).
18. F. Celani, A. Spallone, L. Liberatori, F. Croce, L. Storelli, S. Fortunati, M. Tulni and N. Sparvieri. Search for Enhancement of Neutron Emission from Neutron-Irradiated, Deuterided, High- Temperature Superconductors in a Very Low Background Environment. *Fusion Tech.* 22, 181 (1992).
19. S. E. Jones, D. E. Jones, D. S. Shelton and S. F. Taylor. Search for Neutron, Gamma and X-Ray Emission from Pd/LiOD Electrolytic Cells: A Null Result. Trans. *Fusion Tech.* 26, 143 (1994).
20. E. Storms. A Critical Review of the "Cold Fusion" Effect. *Fusion Techn.* (to be published).
21. V. I. Visotskii and R. N. Kuz'min. Kanalirobanie Nietral'nib Tyastiz i Kbantob b Kristallaxa. *Uspehi Phizityeskix Nauk* (in Russian) 162 1 (1992).
22. D. S. Gemmell. Channeling and related effects in the motion of charged particles through crystals. *Rev. Mod. Phys.* 46, 129 (1974).
23. P.K. Iyengar and M. Srinivasan. Proc. First Annual Conf. Cold Fusion, Salt Lake, 1990 cited in M. Srinivasan, *Current Science* 60 (1991) 417.
24. M. Nakada, T. Kusunoki and M. Okamoto. Energy of the Neutrons Emitted in Heavy Water Electrolysis. *Frontiers of Cold Fusion*, p. 173, ed. H. Ikegami, Universal Academy Press (Tokyo) (1993); T. Sato, M. Okamoto, P. Kim, Y. Fujii and O. Aizawa. Detection of Neutrons in Electrolysis of Heavy Water. *Fusion Tech.* 19, 357 (1991).
25. H. Long, S. Sun, H. Liu, R. Xie, X. Zhang and W. Zhang. Anomalous Effects in Deuterinm/Metal Systems. *Frontiers of Cold Fusion*, p. 447, ed. H. Ikegami, Universal Academy Press (Tokyo) (1993).

SOME EXPERIMENTS ON THE VARIATION OF THE RADIOACTIVITY OF TRITIUM ABSORBED BY TITANIUM

Abstract of a paper read at ICCF-5

Otto Reifenschweiler
Philips Research Laboratories
Eindhoven, The Netherlands

Small amounts of tritium are sorbed by titanium preparations consisting of small monocrystalline particles ($\phi \cong$ 15 nm) obtained by gas evaporation. In a first experiment, a $TiT_{0.0035}$ preparation is heated and the radioactivity, A, is measured via the X-radiation detected by a GM-tube. The radioactivity decreased from the initial value down to 72% at 160° C, further decreased to 60% at 275° C, and increased again to the initial value at 360° C before decomposition of the preparation. It is shown that, during the whole temperature trajectory up to 360° C, no loss of tritium has occurred and that the decrease of the count rate is entirely due to the decrease of tritium radioactivity. A detailed analysis of the generation of the X-radiation shows that it is not possible to explain the course of A = f(t) by changes from chemi-absorption at the surface to bulk absorption of the tritium in the small Ti particles as has been claimed recently. In a second important heating experiment with a $TiT_{0.035}$ preparation, the tritium is desorbed during heating on account of the 10 times higher concentration and the tritium released from the preparation is measured by a second GM-tube. By addition of the two radioactivities, that remaining in the solid and that expelled as a gas, it is shown that the course of A = f(t) is equivalent for both experiments carried out under very different conditions. In a further heating experiment with a $TiT_{0.065}$ preparation where the surface of the Ti particles is oxidized, a course of A = f(t) of the same kind as that for the first experiment is obtained. The evaluation of these three heating experiments done under very different conditions gives a high degree of evidence for the decrease of tritium radioactivity.

A first attempt is presented to explain this remarkable effect in terms of a nuclear pair hypothesis.

There is strong suspicion that the two different effects, cold DD-fusion and the decrease of tritium radioactivity. are caused by the same or by two related fundamental principles. CF

MICROANALYSIS OF PALLADIUM CATHODES AFTER ELECTROLYSIS IN ACIDIFIED HEAVY WATER

S. Miguet and J. Dash
Physics Department
Portland State University
Portland, Oregon

Previously, we reported finding localized concentrations of unexpected elements on palladium cathodes after electrolysis in an electrolyte containing H_2SO_4 and D_2O [1,2].

Recently, chemical analyses of palladium 0.35 mm thick, used as a cathode for 25 hours and then inadvertently as an anode for 170 minutes, were performed with an energy dispersive spectrometer attached to a scanning electron microscope.

Because of the anodic thinning of the electrode on the lower part in the last experiment, we were able to study the core of the material. Localized concentrations of aluminum and titanium were found at surface protrusions or depressions on the lower part of the palladium where the metal dissolved. It seems unlikely that aluminum and titanium were deposited from impurities in the system because neither element was detected in prior chemical analyses of the electrode materials.

Near the electrolyte level, a black blob with fibers appeared on the anode side of the palladium after the first 10 hours of electrolysis. This surface feature persisted through 15 additional hours of electrolysis as a cathode, followed by 170 minutes as an anode, and then by ultrasonic cleaning in deionized water. A series of analyses of the same portion of this feature over a period of several weeks showed that changes were occurring with time. These include growth of palladium sulfate crystals, bulges in the fibers, and the occurrence of silver, which appeared to change to cadmium as time progressed.

These results seem consistent with the suggestion of Savvatimova, Kucherov and Karabut [3] that the reason for the appearance of unexpected elements is fusion-fission nuclear reactions in the cathode. This conclusion is supported by our discovery of large, localized concentrations of aluminum and cadmium on an electrolyzed palladium cathode 15 months after localized concentrations of silver were observed near areas where the cathode had melted [2]. CF

References

1. D.S. Silver, J. Dash, and P . Keefe. Surface Topography of a Palladium Cathode After Electrolysis in Heavy Water. *Fusion Technology* 24, 423 (1993)
2. J. Dash, G. Noble, and D. Diman. Surface Morphology and Microcomposition of Palladium Cathodes after Electrolysis in Acidified Light and Heavy Water: Cor-