Excess Heat and Helium Generation in CF Experiments

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Abstract

The simultaneous generation of excess heat and helium-4 (^{4}He), observed several times in experiments, is explained in TNCF model of cold fusion. Qualitative consistency of the explanation with other cold fusion phenomena substantiate the reality of Trapped Neutron Catalyzed Fusion of hydrogen isotopes in solids.

1. Introduction

A recent review of experimental works in cold fusion[1] pointed out a remarkable fact in the cold fusion phenomenon about a relation between excess heat and helium observed in ambient gases in the experiments. The experimental data cited in the review[1], some of which are repeated in this paper[2~5], show an apparent correlation in the amounts of these quantities, showing that the helium generation is responsible or has a close relation with the excess heat generation in those experiments. A recent report in another type of samples[6] show a similar relation between excess heat and helium generations in the sample. On the other hand, however, there are a lot of examples which show only excess heat generation without helium[7,8].

These facts tell us that we have to take experimental results with reservations, and not simply deny unobserved quantities as not existing.

Furthermore, the recent experiment[6] with micro particles of palladium showed the existence of helium in the metal sample differing from the well known results of helium only in the ambient gases and not in the samples[1]. This result also tells us that we have to be careful to come to conclusions about the origin of the helium either in or on the sample. Therefore, perhaps, it is better to take quantities once observed as results of real phenomena, and the quantities should be assumed as existing virtually, even if they are not observed. The reason for the failure of observation can be given by the disappearance of them from the experimental region by an interaction with other particles which did not exist in the observed case.

As was pointed out in the review[1], the amounts of the observed helium were considered to correspond to the amount of the observed excess heat in orders of magnitude. This fact leads someone to consider that a special d–d fusion is producing helium in solids, while it is considered difficult to occur in vacuum. Before going too far from conventional physics, it is necessary to use it fully if it is possible to explain a new phenomenon. The model using the trapped neutron as a catalyst to fuse hydrogen isotopes is one of those trials. The physical reasoning of the bases of the model were given in a previous paper[9]. In this paper, an explanation of the occasional correlation between the excess heat and helium generations is given on the trapped neutron catalyzed model for cold fusion.

2. TNCF Model

The TNCF model tells us that nuclear reactions occur stochastically by the existence of the trapped neutron. The starting reaction is the trigger reaction between the trapped neutron with thermal energy and an occluded deuteron (proton) on an interstitial site:

$$n + p = d(1.33\text{ keV}) + \gamma(2.22\text{ MeV}), \quad (1)$$
$$n + d = t(6.98\text{ keV}) + \gamma(6.25\text{ MeV}), \quad (2)$$
$$n + {}^6\text{Li} = {}^4\text{He}(2.1\text{ MeV}) + t(2.7\text{ MeV}) \quad (3)$$

In these formulas , a reaction with a lithium isotope expected in electrolysis experiments is included.

In the following, only reactions relevant with deuterides will be considered. The products of the reaction (2), a triton and a photon, will induce following events in the sample.

First, the triton with medium energy (~7 keV) generated in this reaction makes interaction with occluded deuterons and with matrix nuclei. Let us take up now only the interaction with deuterons; elastic scattering and fusion and disintegration reactions:

$$t + d = t' + d', \quad (4)$$
$$t + d = {}^4\text{He}\ (3.5\text{ MeV}) + n\ (14.1\text{ MeV}), \quad (5)$$
$$t + d = t' = p + n. \quad (6)$$

The fusion cross section of the reaction (5) is about 1 mbarns for this case (7 keV triton). The accelerated deuteron in the scattering (4) interacts with occluded deuterons and with matrix nuclei. Here again, we take up only interactions with deuterons:

$$d + d' = d'' = d''', \quad (7)$$
$$d + d' = {}^3He\ (820\ keV) + n\ (2.45\ MeV), \quad (8)$$
$$= t\ (1.01\ MeV) + p\ (3.02\ MeV), \quad (9)$$
$$d + d' = d'' + p + n. \quad (10)$$

The fusion cross section of the reaction (8) and (9) is about 0.1 mbarns for this case (5 keV deuteron). The neutron with energy 14.1 MeV generated in the reaction (5) interacts especially with occluded deuterons to accelerate and dissociate them besides the interactions with matrix nuclei:

$$n\ (14.1\ MeV) + d = n' + d', \quad (11)$$
$$n\ (14.1\ MeV) + d = n' + p + n'' \quad (12)$$

Those disintegration reactions (6), (10) and (12) are endothermic, producing low energy neutrons, and can be a part of chain reactions for breeding of nuclear products in optimum situations, but not excess heat. Secondly, the photon with an energy of 6.25 MeV generated in the reaction (2) can disintegrate an occluded deuteron to generate a proton and a neutron having energy of about 2 MeV each:

$$\gamma(6.25\ MeV) + d = p + n. \quad (13)$$

The cross section of the reaction (13) is about 1 mbarns for this case (6.25 MeV photon)[10]. This is also the endothermic reaction.

One of the questions raised in the interpretation of CF phenomenon within the limits of conventional physics is the absence in the experimental data of the photon with energy 6.25 MeV generated in the trigger reaction (2) and the neutron with energy 14.1 MeV generated in the reaction (5)[4]. A solution of this question was given in a previous paper[10].

3. Excess Heat and Helium Generations

We start the investigation of the excess heat and helium generations in Pd/D samples prepared by the electrolysis assuming the existence of the trapped neutrons which was shown possible in samples with inhomogeneous structure[9].

On the surface of palladium occluded deuterium by electrolysis with heavy water there are surface layers of PdD_x and $PdLi_y$ alloys. The thickness of the former may be larger than the latter because of the difference of the diffusion constants of D and Li in Pd. Those surface layers work as a wall to confine the thermal neutrons in the sample.

In the case of the volume sample such as used in Fleischmann and Pons[2] and Bush et al[3,4], the thermal neutrons could be trapped by the band gap mechanism[9]. The trapped neutron could interact with deuterons and Li atoms in the surface layers. The reactions (2), (3) and (5) occur there, producing excess energy and helium. It should be noticed that the excess energy is not only produced by reactions (3) and (7), generating helium, but also by reactions (2), (8) and (9), not genera helium. The generated hel atom is in the surface layers w the reactions occur at first, migrate out into the ambient The approximate proportion between the amounts of ex heat and helium is understand from the relation of those r tions.

In the case of the sample fine particle structure[6], the cluded deuteron could be dis uted throughout the sample w the Li atoms are in the sur layer of $PdLi_x$ alloy. The the neutrons could be trapped by total reflection mechanism also by the band gap mechan which is different from the ca the volume sample. The tra neutron interacts with deutero the body of the sample and Li atoms in the surface la Nuclear reactions similar to t occurred in the case of the vol sample to produce excess hea helium.

The reactions listed ab should generate more parti than helium. This problem is explained in this paper, as decl in the last paragraph but two o section 1 that there are no de tions of tritium, especially, i experiments observing hel cited above[2~4,6].

4. Conclusion

The experimental result the excess heat and helium erations taken up here provi fairly solid basis for the estab ment of the cold fusion phen enon. A different experiment a layer structure and light or he water[11~13] shows the high ciency of the layer structure for realizing a nuclear reaction in solids. In this case, a multi-layer structure of Ni and Pd with a thickness ~ 1μm is formed on a surface of small sphere of diameter 1 mm made of resin. The layer occluding hydrogen or deuterium can trap thermal neutrons by the Ni-Pd-Ni multi-layer the boundaries of the layers working as reflector of the neutron by band gap and/or total reflection mechanisms. In the case of hydrogen, the trigger reaction is the reaction (1) and the following reactions could not generate helium. Only the reaction generating helium is the reaction (3). The detection of helium in light water experiment is predicted to be rare from TNCF model. On the other hand, in the case of deuterium, as explained above, helium generation is expected starting from the trigger reaction (2) and the following breeding reactions (5) and others in addition to the reaction (3).

A subtle evidence of the occurence of the reaction (5) had been detected by fine experiment using 150 keV deuteron beam measuring 14.1 MeV proton signal. Our interpretation of the signal is that it is made by a proton recoiled by 14.1 MeV neutron generated in the reaction (5).

About the quantitative estimation of the reaction rates, it is difficult to calculate them exactly. The cross sections of reactions (5), (8), (9) and (13) are in the range of 1 mbarns in the relevant energy regions. This value is two or three orders too small to substantiate those reactions in samples used in the usual experiments without some new factors. One positive factor is the channeling of charged and neutral particles in crystal. The starting point of generated particles in the trigger reaction is an interstitial site. In this case, the particles so generated can travel through a channel effectively, colliding with occluded hydrogen isotopes with effective particle density one or two orders magnitude higher than that in vacuum.

On the other hand, the cross section of the reaction (3) for a thermal neutron is about 1 barn[15]. This value is very large in the standard of the nuclear reaction and gives us hope as an explaination for the main part of the observed helium by this reaction when there is a lot of trapped neutrons and lithium nuclei. Furthermore, the triton with 2.7 MeV generated in the reaction (3) has a large cross section about 10 barns for the reaction (5) generating ^{4}He and a neutron. In deuterides with ^{6}Li on the surface layer, therefore, helium generation occurs very effectively.

There are also several heat generating reactions besides the reactions generating helium in the sample. Therefore, the number of events generating helium is not enough to explain the number of events generating excess heat. In the reivew[1], those experimental data were shown with a reference line based on the d - d reaction generating a helium nucleus and an energy 23.8 MeV as recopied in Fig. 1 (Fig. 2 of Ref.(1)). The graph shows that even in this large energy generated with one events (the solid line), the excess power is about 1.5 times higher than the helium generating events (the dotted line). Taking the usual reaction energy of several (take 5) MeV per an event, there are six times more events generating energy than the events generating helium.

The cross section of the reaction (12) for a neutron with an energy 14 MeV is about 0.2 barns[15]. This is also a fairly large value and advantageous for the breeding of neutrons in a cycle of reactions (2), (5) and (12).

Considering the complicated situation in cold fusion materials, it is reasonable to assume that several reactions (2), (3), (5), (8), (9), (12)and (13) occur for helium generating reactions (3) and (5). The problem of the lack of detection of other nuclear products other than helium are fundamentally neglected in this discussion as explained above.

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References

(1) E. Storms, "Status of 'Cold Fusion'" *Proc. ICCF5* (April 9–13, Monte-Carlo, Monaco), 1 (1995).
(2) J.R. Morrey, M.R. Caffee, H. Farrar, IV, N.J. Hoffman, G.B. Hudson, R.H. Jones, M.D. Kurz, J. Lupton, B.M. Oliver, B.V. Ruiz, J.F. Wacker and A. Van, "Measurements of Helium in Electrolyzed Palladium," *Fusion Technol.* 18, 659 (1990).
(3) B.F. Bush, J.J. Lagowski, M.H. Miles and G.S. Ostrom, "Helium Production During the Electrolysis of D_2O in Cold Fusion," *J. Electtroanal. Chem.* 309, 271

(1991).
(4) M.H. Miles, B.F. Bush and J.J. Lagowski, "Anomalous Effects involving Excess Power, Radiation, and Helium Production during D_2O Electrolysis using Palladium Cathodes," *Fusion Technol.* 25, 478 (1994).
(5) 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.
(6) Y. Arata and Y-C. Zhang, "Achievement of Solid-State Plasma Fusion ('Cold Fusion')," *Proc. Japan Acad.* 70B, 106 (1994); ibid, 71B, 304 (1995).
(7) M. C. H. McKubre, S. Crouch-Baker, R. C. Rocha-Filho, S. I. Smedley, F.L. Tanzella, T. O. Passell and J. Santucci, "Isothermal Flow Calorimetric Investigations of the D/Pd and H/Pd Systems," *J. Electroanal. Chem.* 368, 55 (1994).
(8) M. C. H. McKubre, S. Crouch-Baker and F. L. Tanzella, "Conditions for the Observation of Excess Power in the D/Pd System," *Proc. ICCF5* (April 9–13, Monte-Carlo, Monaco) 17 (1995).
(9) H. Kozima, "Neutron Band, Neutron Cooper Pair and Neutron Life Time in Solid," *Cold Fusion*, 16, (1995); Proc. 3rd Russian Conference on *Cold Fusion and Nuclear Transmutation* (Sochi, Russia, Oct. 1995)(to be published).
(10) H. Kozima, "On the Absence of Photon with 6.25 MeV and Neutron with 14.1 MeV in CF Experiments," *Cold Fusion* 15, (1996).
(11) U.S. Pats No. 5,318,675, "Method for Electrolysis of Water to form Metal Hydride."
(12) U.S. Pat. No. 5,372,688, "System for Electrolysis of Liquid Electrolyte": and also Report by V. Lapuszynski, "The Patterson Power Cell™," *Cold Fusion,* 7, 1 (1995).
(13) D. Cravens, "Flowing Electrolyte Calorimetry," *Proc. ICCF5* (April 9–13, Monte-Carlo, Monaco) 79 (1995).
(14) J. Kasagi, K. Ishii, M. Hiraga, and K. Yoshihara, "Observation of High Energy Protons Emitted in the TiD_x+D Reaction at E_d=150 keV and Anomalous Concentration of ^{3}He," *Frontiers of Cold Fusion,* p. 209, ed. H. Ikegami, Universal Academy Press (Tokyo), 1993.
(15) T. Nakagawa, T. Asami and T. Yosida JAERI-M 90-099 NEDAC(J)INOC (jpn)-140/L.

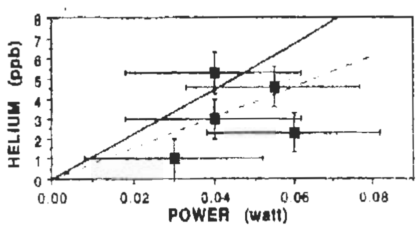

Fig. 1. Helium produced as a function of excess power. Relationship based on d + d = He + 23.8 MeV shown as line. The helium concentration results from a constant current of 500 mA held for a constant time. Collection was done using a metal system.