Explanation of Experimental Data of X-ray, Heat Excess and ^{4}He in a PdD_x/Li System

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Abstract

Experimental data using the X-ray, the excess heat and ^{4}He in PdD_x/Li cathodes were analyzed using the TNCF model. A quantitative relation between the number of ^{4}He atoms and the amount of the excess heat generated in the cathodes were consistently explained using a single adjustable parameter n_n, density of the trapped thermal neutron, the value of which was determined as ~10^9 cm^{-3}. A ratio of the numbers of the events N_Q generating the excess heat Q and N_{He} were evaluated from the experimental data as 1~ 5 while the theoretical value was 1 using the model.

1.Introduction

Elaborate experimental works[1-4] done by a group in the University of Rome after the discovery of the cold fusion phenomenon in 1989 have shown the reality of the excess heat generation in the PdD_x/Li cathode though the nuclear products had not been proved their existence until ^{4}He was detected in a recent work[4].

The report[4] given in the ICCF6 (Hokkaido, Japan, October 1996) has shown the simultaneous generation of the excess heat up to 80 % of the input energy and of ^{4}He well above the background level. The X-ray of an energy 89 ± 1 keV was measured and identified its origin as from the central part of the cathode which was a bundle of Pd wire of a diameter 250 μm and a length 40 mm. This result showed clearly that the origin of the excess heat was a nuclear reaction in or on the Pd wire of the cathode.

The authors of the work[4] analyzed their data on an assumption that the nuclear reaction was:

$$d + d = {}^4\mathrm{He} + \gamma(23.8\ \mathrm{MeV}). \qquad (1)$$

They concluded on this assumption that the ratio of the events generating the excess heat N_Q and helium N_{He} was smaller than unity; $N_Q/N_{He} \leq 1$, with almost all values in a range 0.2 ~ 0.4.

We will analyze these data on the TNCF model.

2.Analysis of the Experimental Results

The fundamental postulates of the TNCF model[5–7] are stable existence of the trapped thermal neutron with a density n_n, which is an adjustable parameter to be determined by the experimental data and its fusion reactions with another nucleus causing a large perturbation on the trapped neutron itself.

To analyze the experimental data[4] of the excess heat and ^4He generation, we will take up only the following reaction in the surface layer of PdLi alloy on the Pd cathode caused by the thermal neutron for simplicity:

$$n + {}^6Li = {}^4He + t + Q_l, \quad (2)$$

where $Q_l = 4.8$ MeV.

Our assumption in the TNCF model is the observed excess heat Q ~ 5 W from Fig. 1 (Fig. 3 of Reference 4) was generated by the reaction (1) in the surface layer of the PdLi alloy with a thickness $l_0 \sim 1\ \mu m$ where the abundance of the isotope ^6Li was assumed as the same as the natural one (7.4 %).

Then, the excess heat Q in time τ is expressed as follows:

$$Q = 0.35 n_n v_n n_{Li6} l_0 S \sigma_{n\text{-}Li6} Q_l \tau. \quad (3)$$

In this relation, $0.35 n_n v_n$, is the thermal neutron flux in the sample per unit area and unit time, S is the surface area of the cathode and σ is the fusion cross section; $s_{n\text{-}Li6} = 9.4 \times 10^2$ barns. From the geometry of the cathode (150 wires of a diameter 250 μm and a length 40 mm), we obtain $S = 4.7 \times 10\ cm^2$. With the velocity of the thermal neutron $v_n = 2.7 \times 10^5$ cm/s (300 K), $n_{Li6} = 3.4 \times 10^{22} \times 0.074\ cm^{-3}$ and $Q = 5$ W, we obtain the density of the trapped thermal neutron:

$$n_n = 2.2 \times 9^{10}\ cm^{-3}. \quad (4)$$

This value is reasonable one compared with values [7] obtained for other samples with different conditions.

Taking only the reaction (1), theoretical ratio of the numbers of events N_Q and N_{He} is 1 while the experimental value is in the range 1 ~ 2 with a maximum 5 because of the value $Q_l = 4.8$ MeV instead of 23.8 MeV in Eq. (1)

$$(N_Q/N_{He} \leq 5).$$

Considering a possibility of such reactions as written down below induced by the high energy particles ^4He and t generated by the trigger reaction (1) generating the excess heat with and without ^4He, we can expect the ratio N_Q/N_H, to be larger than 1:

$$t\,(2.7\text{ MeV}) + d = {}^4He\,(3.5\text{ MeV}) + n\,(14.1\text{ MeV}) + 2.7\text{ MeV}, \quad (5)$$

$$n\,(14.1\text{ MeV}) + d = n'\,(e) + d'\,(e'), \quad (6)$$

$$n\,(14.1\text{ MeV}) + d = n'(e) + p\,(e') + d'\,(e''), \quad (7)$$

$$n + d = t + \gamma + 6.25\text{ MeV}, \quad (8)$$

$$n + p = d + \gamma + 2.2\text{ MeV}, \quad (9)$$

$$n + {}^7Li = {}^8Be = 2\,{}^4He + e^- + \nu_e + 16.2\text{ MeV}, \quad (10)$$

$$n + {}^AM = {}^{A+1}M' + e^- + \nu_e. \quad (11)$$

The amount of tritium almost zero[2] or small compared with the excess heat[3] in the former experiments is a riddle not resolved by the TNCF model which successfully analyzed many experiments[7-10] where much tritium was observed. Perhaps, the riddle might be solved by more careful investigation of the system PdD./Li generating the excess heat and ^{4}He.

3. Conclusion

The TNCF model[5,10] has explained consistently a series of data obtained in the cold fusion

experiments. Especially, the riddles of the cold fusion phenomenon, the huge excess heat, the large N_t/N_n, ratio, the generation of ^{4}He and the poor reproducibility had been solved which was impossible to explain by following simple fusion reactions between light nuclei, even if they occurred with a high probability:

$$d + d = t + p, \qquad (12)$$
$$= {}^4\text{He} + n, \qquad (13)$$
$$= {}^4\text{He} + \gamma. \qquad (14)$$

The experimental data[1-4] obtained in this last 5 years show clearly the complexity of the cold fusion phenomenon. For instance, the data in Fig. 1 show the characteristics of the phenomenon: long time (~ 200 h) before the generation of the excess heat, sporadic nature of the excess heat generation after the first signal, qualitative reproducibility of the excess heat and helium generations.

Those characteristics can be explained by the TNCF model which assumes stable existence of the trapped thermal neutron in the sample. The condition for the neutron trapping is governed by atomic processes occurring in the sample which are stochastic from their nature. This is the reason that the cold fusion phenomenon has the qualitative reproducibility but the quantitative.

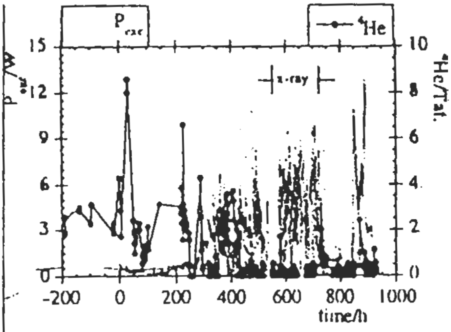

Fig. 1. Excess heat power P_{exc}/W (left scale) and ^{4}He/Tat.(tera-atom) (right scale) in an experiment with bundle-type cathode (250 μm dia. wire) (Fig. 3 of Reference 4).

Recently, nuclear transmutation (NT) is attracting much attention from researchers in this field. The TNCF model could explain NT in several cases[11] though there remain many data waiting explanation. Also explained were data from metal-hydrogen systems generating large excess heat[12].

The analyses of those experimental data by the TNCF model depict the physics of the cold fusion phenomenon predicting some new effects for further development of the solid state nuclear physics.

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