TNCF Analysis of Excess Heat Data in Pd/D/Li System

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Synopsis

Data of careful calorimetric measurements of excess heat from Pd wire cathodes in D_2O + LiOD electrolytic solution obtained by Ota et al. were analyzed using the TNCF model. A consistent explanation of the data was obtained with the arbitrary parameter in the model - the density n_n of the trapped neutron - of $10^9 \sim 10^{10}$ cm^{-3}.

1.Introduction

The TNCF model for the cold fusion phenomenon has been used to explain various cold fusion events measured in materials containing hydrogen isotopes with a great success[1-3]. There are too many experimental data to treat in a short time since the accomplishment of the model about two years ago. We are going to analyze the remaining excellent data obtained in these 8 years after the discovery of this phenomenon using the TNCF model. In this paper, we have taken up one of data obtained by Ota et al.[4-6]

2. Experimental results

2-1. Excess heat with Pd cathode

The heat balances have been measured[4] during the electrolyses in LiOD + D_2O and H_2O + LiOH solutions (18 runs with D and 4 runs with H) using Pd and $Pd_{1-x}Ag_x$ (x= 0.1 and 0.15) alloy cathodes. The flow calorimeter and the closed cell with Pd recombination catalysts were used for heat measurement.

The D/Pd ratio was up to ~ 0.85. In four out of 18 runs with D showed the remarkable maximum excess heat from 9 to 74 % of input energy (~ 2 - 10 W). In four runs (9, 14, 17 and 22), the excess heat was observed as a burst. The mechanically treated Pd cathodes were used in runs 9, 14 and 17. The largest excess energy of 74 % was obtained in a cathode $Pd_{0.9}Ag_{0.1}$ with a size of 4 mmø x 15 mm with 1M LiOD when the electrolyzing current densities of 260 ~ 180 mA/cm^2 and the input energy of 2 W (run 22). The excess heat could not be explained as due to hidden chemical reactions not noticed in the present experiments.

In accordance with general tendency with the cold fusion phenomenon, the excess energy generation, if any, had occurred after a long preceding period; for example in run 13, the period was 1150 h and the average excess heat of 6.5 % lasted 220 h with a maximum (burst) of 13 %.

We have to notice that the poor reproducibility (4 out of 18 runs with D), a long preceding period (e.g. 1150 h in the case of the run 14) and unstable heat generation (e.g. 6.5 % in average and 13 % at burst in the run 14) are commonly recognized features of the cold fusion phenomenon.

2-2. Excess heat with Pd(B) cathode

On another experiment[5], Ota et al. observed effect of boron B added to Pd cathode on the excess heat production. The contents of B in Pd was 10^2 ~ 10^3 ppm. In three runs (23, 29 and 33), the maximum excess heat of 7, 5 and 4 % was observed where the input power was 5 W with boron B of 2.67, 5.0 and 5.0 x 10^2 ppm, respectively. The cathode was Pd(B) cylinder (4 mmø x 20 mm)(run 23) and Pd(B) plate (1 x 2 x 20 mm) (runs 29, 33). The excess heat was observed in three runs (23, 29 and 33) using boron added Pd cathodes continuously.

2-3. Excess heat with Modified Pd cathode

Pd(B) (4 mmø x 15 mm) and Ni (1 ~ 10 μm) coated Pd (2 mmø x 15 mm) cathodes were used in 1M LiOD + D_2O electrolytic solution. The S/V ratio is 11.3 cm^{-1} in the Pd cathode. There occurred two heat bursts in Pd(B) cathode case (N1-03). The maximum excess heat at a burst was 1.8 W or 136 % of the input energy in run Nl-03.

3. Analysis of the Data by the TNCF Model

Using the recipe described in the preceding papers[1-3], we can explain the data showing the excess heat was too large to explain by and chemical reaction obtained by Ota et al.[4,5] The TNCF model assumes existence of the trapped thermal neutron with a density n_n in a sample as an adjustable parameter.

The most probable nuclear reaction in the electrolytic system with D_2O electrolyte is the following ones in the surface layer of Li metal and/or $PdLi_x$ alloy with the assistance of a deuteron-rich PdD_x layer near the surface (in contrast to the relative absence of a hydrogen-rich layer in the case of a system with H):

$$n + {}^6\mathrm{Li} = {}^4\mathrm{He}\ (2.1\ \mathrm{MeV}) + t\ (2\text{-}7\ \mathrm{MeV}), \quad (1)$$
$$t + d = {}^4\mathrm{He}\ (3.5\ \mathrm{MeV}) + n\ (14.1\ \mathrm{MeV}), \quad (2)$$
$$n + d = t\ (6.98\ \mathrm{keV}) + \gamma (6.25\ \mathrm{MeV}). \quad (3)$$

The preceding period in the experiment is supposed to be necessary to form the surface layer of Li metal and/or $PdLi_x$ alloy, the thickness of which has been assumed as 1 μm throughout our analysis. The preceding period is also necessary to accumulate thermal neutrons with a density n_n in the sample supplied by the background neutrons and by breeding processes, the main processes of which were supposed to be the following dissociation ones:

$$n + d = n + p + n, \quad (4)$$
$$\gamma + d = p + n. \quad (5)$$

These processes are absent in Pd/H/Li system and are a cause of the difference from the Pd/D/Li system.

The number N_N of a reaction between the trapped neutrons and the nucleus N is related with the density of the trapped neutron n_n by the following relation;

$$N_N = 0.35 n_n v_n n_N V \sigma_{nN} \xi, \quad (6)$$

where $0.3 n_n v_n$ is the flow density of the neutrons per unit area and time, n_N is the density of the nucleus, V is the volume where the reaction occurs, σ_{nN} is the fusion cross section for the reaction. The factor ξ as taken into the relation (1) expresses an order of the stability of the trapped neutrons in the trapping region. In the case of the reaction (1), the number of events generating ^{4}He N_{He} and that generating tritium N_t is the same to N_N given in the relation (6). The number of events generating the excess heat Q is equal to Q (MeV)/4.8 MeV experimentally and equal to N_N given by the relation (6) theoretically.

3-1. Excess heat with Pd cathode

With the procedure explained before[1-3], we ran calculate the adjustable parameter n_n from the experimental data[4] taking only the reaction 1) in the surface layer of Li metal with $\xi = 1$ in the relation (6) into consideration, for simplicity:

$$n_n = 10^9 \sim 10^{10}, \text{cm}^{-3}.$$

In the four runs with the maximum excess heat of more than 9%, the maximum values are as follows: 1.3×10^{10} cm^{-3} (run 9), 3.5×10^{10} cm^{-3} (run 14), 1.2×10^{10} cm^{-3} (run 17) and 3.6×10^{10} cm^{-3} (run 22). The S/V (surface to volume) ratios of the samples were 9, 8, 10 and 11.3 cm^{-1} in runs 9, 14, 17 and 22, respectively.

3-2. Excess heat with Pd(B) cathode

In the case of B addition to Pd cathode[5], we have to consider also another reaction between trapped neutron and ^{10}B in the volume with $\xi = 0.01$ as shown by Passel[6] and analyzed by us[7] (the natural abundance of ^{10}B is 19.78%):

$$n + {}^{10}\text{B} = {}^7\text{Li} + {}^4\text{He} + 2.79 \text{ MeV}, (93\%) \quad (7)$$

$$= {}^7\text{Li} + {}^4\text{He} + \gamma(0.48\text{MeV}) + 2.79\text{MeV} \ (7\%). \quad (8)$$

The cross section of these reactions is 3.84×10^3 barn.

The data gives following values of n_n;

$$n_n = 6.6 \times 10^9, 1.1 \times 10^{10} \text{ and } 8.4 \times 10^9 \text{ cm}^{-3},$$

for runs 23, 29 and 33, respectively. The S/V ratios of samples in these runs were 11, 31 and 31 cm^{-1}, respectively.

It seems that the addition of boron B in the Pd cathode did not affect the adjustable parameter n_n in any discernible amount. The behavior of the excess heat generation is, however, changed very much. In the presence of boron there was no heat burst, showing clearly the effect of the reaction (7) and (8).

3-3. Excess heat with Modified Pd cathode

The maximum values of n_n determined by the maximum values of Q_{max} in several runs are given as follows:

n_n=7.1, 5.4, 3.4, 3.4, 3.9 and 4.4 x $10^{10}cm^{-3}$,

for runs 23, 29, 31, 33, 48 and K1-03, respectively.

These values of nn_n are consistent in themselves and also in the range of n_n obtained previously for other similar experiments[1-3]. We have to remember an assumption in the calculation of n_n that the liberated energy in the reaction (1) is entirely thermalized in the system.

4.Conclusion

We interpret the above result as showing a success of the model and that the cold

fusion phenomenon is a probe suggesting the existence of the thermal neutron with a quasi-stability piled up in the solid[1] and also the existence of nuclear reactions between the trapped neutrons and nuclei in and on the sample, another evidence of which is the nuclear transmutation[8-10].

Though the data of the excess heat can determine only the value of the adjustable parameter n_n, other events, if any, can support the validity of the model by comparing theoretical and experimental values of such ratios as N_t/N_n, or N_Q/N_n, which had been done before[11].

The value of n_n determined in this analysis will increase by a factor one or two if the liberated energy in the reaction (1) is only partly thermalized in the system though the contribution of other reactions than (1) decrease n_n. The remaining part of the liberated energy might be carried out of the system by the particles t, n and γ in reactions (1), (2) and (3), respectively.

In reality, the photon with an energy 6.25 MeV has been observed in recent experiments[12-14].

Our cold fusion experiments, clearly, are not entirely free from radiation hazards.

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