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Analysis of the Electrolytic Cold Fusion Experiments on TNCF Model

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ABSTRACT

A model based on the stable existence of thermal neutrons in crystals was used to analyze experimental data obtained in electrolytic systems. The density of the trapped thermal neutron n_n in samples was determined using experimental results on the excess heat, helium 4 (^{4}He), tritium and neutron. The values of the density n_n determined by the experimental data were $10^2 \sim 10^{12}$ cm^{-3}. Other quantities which we could determine from experimental data were the ratio of events generating tritium and neutron N_t/N_n and the ratio of events generating the excess heat and tritium N_Q/N_t, which had been a point of controversy in today's physics. The values determined on our model have been $N_t/N_n \sim 10^5$ and $N_Q/N_t \sim 10$, almost consistent with experimental data of a few orders of magnitude.

1. Introduction

In the cold fusion phenomenon, discovered in 1989 and developed in the last seven years, there has been a lot of experimental data which has piled up. Various phases of the results obtained hitherto are lacking a consistent explanation.

The experimental results of the cold fusion phenomenon have been obtained in a variety of materials generating various products including excess heat, ^{4}He, tritium, neutron, γ and the nuclear transmutation. These results were difficult to understand in the framework of conventional physics. Therefore, it became necessary to have a common basis possible to explain all of the data. A model proposed by one of the authors (K.H.) is now being investigated[1~3]. It seems to be able to explain the various events consistently.

2. The TNCF Model

The TNCF (Trapped Neutron Catalyzed Fusion) model assumes the existence of the trapped thermal neutron and its stability. The fusion probability may be calculated

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by the same formula as the usual collision process between a thermal neutron and a nucleus:

$$P_f = 0.35 \, n_n v_n n_N V \sigma_{nN} \tag{1}$$

where $0.35 n_n v_n$ is the flow density of the neutron per unit area and time, n_N is the density of the nucleus, V is the volume of the region where the nucleus fuses with the thermal neutron, and σ_{nN} is the fusion cross section for the reaction.

Typical reactions related with the TNCF model are written down as follows. The trapped thermal neutron can fuse with the ^{6}Li nucleus with a large cross section $\sim 1 \times 10^3$ barns in the surface layer formed on the cathode by electrolysis of $D_2O+LiOD$:

$$n + {}^6\text{Li} = {}^4\text{He} \ (2.1 \ \text{MeV}) + t \ (2.7 \ \text{MeV}). \tag{2}$$
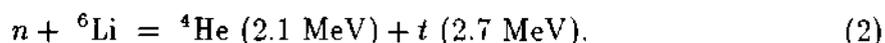
The triton with 2.7 MeV generated in this reaction can pass through the crystal along the channeling axis on which is an array of occluded deuterons or can proceed along a path of finite length ($\simeq 1\sim 10 \ \mu$m) determined by interaction with charged particles in the crystal. In these processes, the triton can fuse with a deuteron with a cross section $\sim 1.4 \times 10^{-1}$ barns:

$$t \ (2.7 \ \text{MeV}) + d = {}^4\text{He} \ (3.5 \ \text{MeV}) + n \ (14.1 \ \text{MeV}). \tag{3}$$
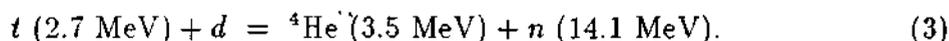
The neutron with 14.1 MeV generated in this reaction can interact with particles, especially with deuterons in the crystal, giving a large amount of energy to the deuteron by elastic collision and dissociating it by inelastic collision. The generated energetic particles sustain breeding chain reactions which produce a lot of the excess heat and nuclear products. Some of the increased thermal neutrons will be captured by nuclei, and cause the nuclear transmutation reactions.

3. Analysis of Typical Quantitative Experimental Data

In measurements of several cold fusion events, it was possible to obtain several quantities simultaneously. Lack of general understanding of relations between physical quantities, however, have made descriptions of the results vague or sometimes, even chaotic. Generally speaking, there were too much data observed without a definite relation between them.

Therefore, it is usually impossible to explain all of the data obtained in an experiment including the interrelated physical variables. For the time being, we will select data from a point of view which neglects others, leaving them for a future program to explain in relation with known factors. We will examine only five events regarding quantitative relations between observed quantities taken from reliable experimental results obtained.

1) M. Fleischmann, S. Pons and M. Hawkins.[4]

From the abundant data in the first cold fusion paper, we examined[5] the case of a thin rod Pd cathode with dimensions 0.4 cmϕ × 10 cm. When the electrolyzing current density was 64 mA/cm^2, the system consisting of a Pd cathode, Pt anode and LiOD+D_2O gave the excess power of 1.75 W ($= 1.1 \times 10^{13}$ MeV/s), tritium atoms

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4×10^{11}/s , and neutrons 4×10^4/s (perhaps in the same sample but not described explicitly).

To analyze this data, we assumed the thickness of the Li atom surface layer (area S) of the cathode as $l_0 = 1$ μm, the natural abundance of ^{6}Li in LiOD at 7.5 %, and the average velocity of the trapped neutron at $v_n = 2.7 \times 10^5$ cm/s (T = 300 K). Then, we could determine the density of the trapped neutron n_n using the relation between n_n and the number of tritium atoms N_t generated in time τ by the reaction (2):

$$N_t = 0.35 \, n_n v_n n_{6Li} l_0 S \sigma_{nLi} \tau, \tag{4}$$

where S = 12.8 cm^2, $\sigma_{nLi} = 10^3$ barns and $n_{6_{Li}} = 3.5 \times 10^{21}$ cm^{-3}. The observed value of N_t per unit time 4×10^{11}/s gave us

$$n_n = 9.4 \times 10^9 \text{cm}^{-3}. \tag{5}$$

The triton generated in the reaction (2) induces the reaction (3), and which produces a neutron with energy 14.1 MeV. Taking the path length of the triton in the cathode PdD$_x$ as $\sim 1\mu$m and using the cross section of reaction (3) for 2.7 MeV triton as $\sigma_{t-d} \sim 1.4 \times 10^{-1}$ barns, and the density of deuterium near the surface layer as 6.8×10^{22} cm^{-3}(D/Pd = 1), we calculated the probability of reaction (3) induced by a triton, as 9.5×10^{-7} which gives a ratio of events generating tritium and neutron,

$$N_t/N_n \sim 1.1 \times 10^6. \tag{6}$$

This value is compared with the experimental value 10^7. Another quantity we can use as an index of the cold fusion phenomenon is the ratio of events producing the excess heat and tritium atoms N_Q/N_t. Assuming that nuclear reactions liberate energy of about 5 MeV per reaction on average, we obtained a value,

$$N_Q/N_t = (1.1 \times 10^{13} \div 5)/(4 \times 10^{11}) = 5.5. \tag{7}$$

This value suggests that the origins of the excess heat are the n + ^{6}Li reaction and several other reactions which follow.

2) A. Takahashi, T. Iida, T. Takeuchi, A. Mega, S. Yoshida and M. Watanabe.[6]

Next, we will take up an experiment which observed the excess heat, tritium and neutron in Pd/D$_2$O+LiOD system with L-H mode electrolysis. The dimensions of the Pd cathode were 20 mmϕ $\times$ 30 mm and a surface area S = 25 cm^2. The total number of observed neutrons was 6.8×10^6, and that of tritium measured in the solution was 4.2×10^{11}. Then,

$$N_t/N_n = 8.7 \times 10^4. \tag{8}$$

This value has only one order of magnitude difference with the value of Eq.(6) which is also applicable in this case.

Besides, we obtained[7] the density of the neutron in the sample as $n_n \sim 10^2$ cm^{-3} by using Eq.(4). In this calculation, we assumed the time duration τ of tritium generation as a month by looking at the experimental data. This value of n_n is a little too small,

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but not too troubling. It's natural that there are differences in capability of neutrons because of the condition or the history of samples.

3) M.H. Miles, R.A. Hollins, B.F. Bush and J.J. Lagowski.[8]

Third, we will give a result of the analysis[5] of an experiment which observed excess heat and helium in $Pd/D_2O+LiOD$ system using a massive cylindrical Pd cathode with a surface area of 2.6 cm^2. They measured $10^{11} \sim 10^{12}$ ^{4}He atoms/s per watt of excess power in the ambient gas. Similar analysis, as given above, resulted as follows:

$$n_n = 10^9 \sim 10^{10} cm^{-3}, \quad N_Q/N_{He} \sim 10. \tag{9}$$

4) C.C. Chien, D. Hodko, Z.Minevski and J. O'M. Bockris.[9]

Fourth, we will give a result of the analysis of an experiment which observed the concentrations of tritium and ^{4}He in $Pd/D_2O+LiOD$ system. In their paper, the total number of tritium atoms was evaluated as $\sim 10^{11}$ in the cathode, and as $\sim 10^{15}$ in the whole system (including the electrolyte and gas). The number of ^{4}He atoms was evaluated only in the cathode sample as 0.4 $\sim$ 166.8 $\times 10^9$. In the surface layer, the n + ^{6}Li reaction generated tritium and ^{4}He, while the n + d reaction generated tritium in the volume. Therefore a direct comparison of the numbers of tritium and ^{4}He is difficult, though the observed numbers are not inconsistent with our model.

The neutron density was evaluated using the maximum value of tritium production rate in the total system, 3.8 $\times 10^7$ atoms/s cm^2, as follows:

$$n_n = 1.1 \times 10^6 cm^{-3}. \tag{10}$$

5) Y. Arata and Y.C. Zhang.[10]

Finally, we will give a result of the analysis of an experiment which observed a huge excess heat (several hundred MJ/cm^{-3}) for over several months and a tremendous number of helium atoms as high as $10^{20} \sim 10^{21}$ cm^{-3} in Pd-black contained in a Pd cylinder cathode as follows:[11]

$$n_n \sim 10^{12} cm^{-3}, \quad N_Q/N_{He} \sim 4. \tag{11}$$

Because of the ambiguity in the description of the results in their papers, we had to assume concrete numerical values for the amount of excess energy at 3 $\times 10^9$ J, and a time duration r of 1 $\times 10^7$ s. These results are also consistent with others.

4. Conclusion

The analyses of experimental data on the TNCF model gave us a unified view of the physics of cold fusion. Though the analyses given above have been confined to the experiments with electrolysis, the results were remarkable. The reliable data showed clearly, facets of the truth. Only assuming the existence of the stable thermal neutrons in cold fusion materials, can we have a consistent understanding of events in the phenomenon with quantitative relationships in them. (It is unavoidable that these results have errors in a range of a few figures, because of the numerical ambiguities included in data and our assumptions.) The success of these analyses suggests the reality of the concept of the trapped neutron.

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The other three papers[12~14] given in this conference will help the reader to understand the physics of cold fusion.

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