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First reliable tritium data by Packham et al. analyzed by TNCF model

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Abstract

The first reliable tritium data obtained by Bockris' group in Texas A&M University is successfully analyzed with the TNCF model. The adjustable parameter in the model is determined by the experimental data as $n_n = 3.6 \times 10^7$ cm^{-3} consistent with values determined for other events in the cold fusion phenomenon.

Keywords: Cold fusion; Tritium; TNCF model

1. Introduction

The cold fusion (CF) phenomenon including observations of the excess heat, tritium and neutron by Fleischmann et al. [1], neutron with 2.45 MeV by Jones et al. [2], tritium by Packham et al. [3], ^{4}He in the Pd cathodes generating the excess heat by Morrey et al. [4], and others has been investigated eagerly at first in public and now in a selected community since 1989. Apparent lack of the unified explanation of various features of the phenomenon has given poor popularity in the research and development of this phenomenon recently. The TNCF model for the CF phenomenon proposed by one of the authors (H.K.) in 1993 was applied to the explanation of these [1,2,4] and other data with success [5] and was summarized in a book [6].

In this paper, we analyze the first convincing data of tritium production in a Pd/D/Li system obtained by Packham et al. [3] using the TNCF model with success and consistency with others obtained hitherto and described in the book [6].

2. Experimental data and its analysis

We explain in this section the experimental data by Packham et al. and its analysis by the TNCF model.

2.1. Data by Packham et al. [3]

The first convincing tritium measurement in electrolytic Pd/D/Li system was performed by Bockris' group in Texas A&M University in 1989 soon after the report of Fleischmann and Pons (and Hawkins).

Tritium was detected in gas and liquid in the electrolytic system with Pd wire cathodes (1–6 mmϕ and 1–4 cm long, 99.9% pure), 0.1 M LiOD + D_2O electrolyte (1 l), Ni gauze anodes (99.99% pure). After an electrolysis of 14, 16 or 28 days with a current density of 50 mA/cm^2 followed by an electrolysis with 500 mA/cm^2

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for up to 12 h, samples of electrolyte in the system without and with a gas recombination arrangement were analyzed for tritium by in-situ Liquid Scintillation Counting in the laboratory. The samples analyzed were sent to Los Alamos National Laboratory (National Tritium Center), Argonne National Laboratory, Battelle Pacific Northwest Laboratory and General Motors Research Laboratory with consistent results confirming the data obtained in Texas A&M University.

The corrected tritium activity in dpm/ml (disintegrations per min/ml) was from 1×10^4 to 7.6×10^7 dpm/ml in samples with positive results and less than 400 dpm/ml in samples with negative results.

There are some characteristics of CF events noticed in these experiments: electrodes produced tritium in different time domains, of which some electrodes required lengthy low current density treatment before production. The tritium concentration in solution increases with time until it reaches an asymptote. Tritium production at the electrode ceases after some hours of activity. The electrode surface seems to be involved in the nuclear events implied here. Neutrons comparable to tritium expected from D–D fusion were not observed at all.

2.2. Analysis of the data by the TNCF model

The data of the first convincing tritium detection introduced above is analyzed in this section.

First of all, the fundamental viewpoint of the TNCF model should be explained prior to the analysis of the data to avoid unnecessary confusion in its interpretation. The model is a phenomenollogical one with an adjustable parameter n_n supposed to express the density of the trapped neutron in the sample. Necessity of the existence of neutrons for the CF phenomenon has been shown by precision measurements [7,8] and enhancements of effects in the CF phenomenon by thermal neutrons in several experiments [9–11]. There is also evidence of neutron trapping by CF materials [12,13].

The data support the assumed existence of the trapped neutrons in materials in the TNCF model although its amount remains as an adjustable parameter meaning of which should be explained by a coming microscopic theory of the CF phenomenon. It should be noticed that the amount of the trapped neutron n_n depends on the experimental condition especially on the shape and size of the cathode, thickness of the surface layer formed by electrolysis made of electrolyte, distribution of hydrogen isotope in the cathode, etc.

The reaction assumed for the explanation of tritium production in the electrolytic Pd/D/Li system is the n–^{6}Li fusion reaction in the surface layer formed on the Pd cathode in the process of electrolysis:

$$n + {}^6_3\text{Li} = {}^4_2\text{He}(2.1\ \text{MeV}) + t(2.7\ \text{MeV}). \qquad (1)$$

with a cross section of $\sigma_{nLi} = 9.4 \times 10^2$ barns for a thermal neutron.

For simplicity of analysis, we take up following standardized data for the experimental facts. The size of the Pd cathode is 1 mm$\phi \times 4$ cm, the volume of the electrolytic solution is 1 l, the experimental time is 10 days (8.64×10^5 s) as a whole, the corrected tritium activity is 10^5 dpm/ml. The ^{6}Li abundance in the Li metal used to make LiOD is assumed as the natural one (= 7.4%).

Using these simplified numerical data, we can calculate the adjustable parameter n_n from the number of tritium atoms generated by the reaction (1) using a relation between reaction rate and parameters in the system

$$P_f = 0.35\, n_n v_n n_M V \sigma_{nM} \xi \qquad (2)$$

(Eq. (11.1) in the book [6]) as follows. As the number of disintegration 1 dpm is 1.67×10^{-2} Bq, 10^5 dpm/ml corresponds to 9.35×10^{14} t/l and also to production rate of tritium of 1.1×10^9 t/s (1 Bq of tritium activity means 5.6×10^8 nuclei of ^{3}H).

The volume of reaction region with thickness 1 μm on the surface of the cathode is given as 1.26×10^{-4} cm^3, the average speed of the thermal neutrons is 2.2×10^5 cm/s at 300 K, the density of the ^{6}Li in the surface region is, assuming of Li metal, $4.6 \times 10^{22} \times 0.074 = 3.4 \times 10^{21}$ cm^{-3}, the cross section of the n–^{6}Li fusion reaction is 9.4×10^2 barns and the factor ξ of the TNCF model is 1. These values of parameters inserted into the Eq. (2) give the value n_n of

$$n_n = 3.6 \times 10^7\ \text{cm}^{-3}.$$

This value should be taken with ambiguity factor of an order of one or two, due to the above simplification made in the calculation.

3. Conclusion

The above analysis of the convincing experimental data obtained by Bockris' group in Texas A&M University and confirmed by four authorized laboratories in US has shown again usefulness of the TNCF model for unified interpretation of the cold fusion phenomenon including its qualitative reproducibility.

The value of n_n determined above using the simplification will be increased by a factor of one order of magnitude or two if we use substantial periods of tritium production observed in the experiment. The fine data given in Table 1 of the paper in Ref. [3] shows tritium generation in a definite time range in the experiments but not the whole periods of 14, 16 or 28 days and 12 h explained in Section 2.1.

The tritium measurement by Packham et al. [3] and the helium-4 measurement by Morrey et al. [4] are two convincing data confirming production of new nuclei in the electrolytic Pd/D/Li system. The reason why these data have been thought little of is, perhaps, their inconsistency with the conventional presumption of D–D fusion in the Pd cathode. The group in Texas A&M University tried to detect neutrons consistent with tritium observation [3] but failed from a conventional point of view. The consistent explanation of the convincing tritium data [3] by the TNCF model adds a new proof for the significance of the phenomenological theory to approach the physics of the cold fusion phenomenon, perhaps physics of thermal neutrons in solids with a characteristic composition and structure.

The precise measurement of tritium by Packham et al. [3] corresponds to the ^{4}He detection by Morrey et al. [4] in the Pd cathodes with the excess heat generation provided by S. Pons. The significant amount of ^{4}He in the cathode had been detected in the surface layer with thickness of about 40 μm but the amount inconsistent with the excess heat detected by Pons by a factor 40. There are two invalid assumptions in the analysis of the data [4] by Morrey et al.: (1) ^{4}He is generated by the D–D fusion in the cathode; and (2) generation of ^{4}He in volume of the cathode. A consistent explanation [14,15] of the data by Morrey et al. [4] was given by the TNCF model.

Recent knowledge of behavior of neutrons in such an extreme nuclei as ^{8}He, ^{11}Li, and so forth (neutron halo etc.) and in solids (neutron in artificial potential wells, neutron interferometry, etc.) suggests a possible physical foundation for the TNCF model based on the behavior of neutrons in crystal lattice and their mutual interaction through nuclear force. Details of this phase of the model will be discussed elsewhere.

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