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Tritium and ^{4}He data by Chien et al. confirmed the cold fusion phenomenon

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Abstract

The simultaneous tritium and helium data obtained by Bockris' group in Texas A&M University are analyzed with the TNCF model. The adjustable parameter in the model is determined by the experimental data as $n_n = 1.5 \times 10^6$ cm^{-3} consistent with values determined for other events in the cold fusion phenomenon. To reconcile the data of tritium and ^{4}He, it is necessary to assume that only $1 \sim 10\%$ of the generated ^{4}He remains in the surface region of the cathode where it has been observed.

Keywords: Cold fusion; Tritium; Helium; 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], the nuclear transmutation (NT) and others have been analyzed successfully by the TNCF model giving a unified explanation of various features of the phenomenon. The TNCF model for the CF phenomenon proposed by one of the authors (H.K.) in 1993 was explained and the result of the analyses was given in a book [5] and recent papers [6,7].

We analyze the data of simultaneous observation of tritium and ^{4}He production in Pd/D/Li system obtained by C–C. Chien et al. [8] using the TNCF model with success and consistency with others obtained hitherto and described in the book [5].

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2. Experimental data and its analysis

The first reliable tritium observation in the electrolytic Pd/D/Li system was performed in 1989 by Packham et al. [3] and a reliable ^{4}He observation in 1990 by Morrey et al. [4] in Pd cathode used to generate the excess heat. The latter is the first confirmation of simultaneous production of the excess heat and one of the expected nuclear products, ^{4}He, in a Pd cathode.

The first reliable observation of simultaneous tritium and ^{4}He production was performed by Chien et al. [8] giving data showing coexistence of the two nuclear products and absence of ^{3}He in the electrolytic system Pd/D/Li.

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2.1. Data by C–C. Chien et al. [8]

Detection of tritium, ^{3}He and ^{4}He had been done simultaneously by Bockris' group in Texas A&M University in an electrolytic system Pd/D/Li.

The cathode was a Pd cylinder with a size 1 cmϕ and 1.6 cm long, the anode was a Pt wire 0.5 mmϕ and 100 cm, electrolyte is 0.1 M LiOD in D_2O in a cell with a volume of 80 cm^3. The distance between the working and counter electrodes was 2 mm and yielded an electrolyte resistance of about 10 Ω. The electrolyte liquid was checked for H_2O and determined its content in the liquid as 1.6% after three days and 9.8% after 22 days of electrolysis. Electrolysis took place in periods of up to 750 h.

Tritium in the liquid and in the cathode, and ^{3}He and ^{4}He in the cathode were checked. The cathodes were cut to determine distribution of nuclear products in them. Tritium was observed by liquid scintillation counting and ^{3}He and ^{4}He were by mass spectrometry.

2.1.1. Tritium

Evolution pattern of tritium in the process of electrolysis was determined in the electrolyte of Pd/D Li system. It is interesting that the result shows an initiation period before production of tritium and quenching of production by D_2O addition for make up. The quenched production of tritium was recovered by increased electrode potential to trigger the reaction. Total tritium produced in 761 h is determined as 10^{15} atoms in the gas and liquid assuming the average ratio between tritium in the gas phase and in the liquid as 5. The recorded rate of tritium production varied from about 2.1×10^6 to 3.8×10^7 atoms/cm^{2}s.

2.1.2. Helium

It was concluded that ^{3}He was not detected while tritium and ^{4}He were detected several times well above the background level.

Local distribution of ^{4}He is observed in the Pd cathode. Excess ^{4}He was observed in 9 out of 10 electrolyzed Pd samples cut out from electrodes which produced tritium. The amounts ranged from 0.4 to 166.8×10^{11} atoms/g for samples near the surface of the cathode and from 0.4 to 2.5×10^{11} atoms/g for those away from the surface.

2.2. Analysis by the TNCF model

Analysis of this tritium and ^{4}He data is performed on the TNCF model similar to those given in the previous paper [6,7] for the excess heat and ^{4}He data [4] and also in one [9] for the tritium data [3] where a brief explanation of the TNCF model is given.

The fundamental reaction supposed to occur 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:

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

with a cross section of $\sigma_{n\mathrm{Li}} = 9.4 \times 10^2$ barns for a thermal neutron. The surface layer where occurs this reaction is naturally composed of PdD_x and PdD_xLi_y alloys with a thickness depending on the electrolysis condition ranging from 10^{-1}–10^2 μm. In the following calculation, however, it is assumed that the surface layer is of Li metal with a thickness 1 μm, for simplicity.

Furthermore, the abundance of ^{6}Li in the Li metal used in the experiment is assumed as the same to the natural one (7.4%). The number P_f of reactions (1) in a unit time is given by a formula:

$$P_f = 0.35 n_n v_n n_{\mathrm{Li}} V \sigma_{n\mathrm{Li}} \xi. \quad (2)$$

2.2.1. Tritium

According to the relation (2), the tritium production of 2.1×10^6–3.8×10^7 t/cm^{2}s by the reaction (1) gives the parameter n_n of 8.5×10^4–1.5×10^6 cm^{-3}. This value obtained in the cathode of 1 cmϕ × 1.6 cm is smaller than the value 3.6×10^7 cm^{-3} determined in the previous paper [9] for a thin wire with diameter of 1 mmϕ. This is consistent with general tendency [5] that the larger S/V ratio (the surface-to-volume ratio) of a sample is, the higher the value of n_n for an event occurred in it. The S/V ratio is 4 and 40 cm^{-1} in this (1 cmϕ) and the previous (1 mmϕ) samples, respectively.

2.2.2. Helium

First of all,, the data of no ^{3}He in the cathode is consistent with the TNCF model which predicts no production of ^{3}He in the CF phenomenon triggered by the n–^{6}Li reaction.

The localized existence of ^{4}He in the Pd cathode especially near the surface is explained by the presupposed reaction of the trapped neutron near the surface [5–7]. This is consistent, also, with the experimental data obtained by Morrey et al. [4] where ^{4}He has been detected in the surface layer of a thickness about 40 μm. In the analysis [5–7] of the data of Morrey et al., it was necessary to assume amount of ^{4}He in the cathode is only 3% of total amount produced to reconcile difference between the number of events responsible to the excess heat Q ($N_Q = Q$ (MeV)/5 (MeV) assuming 5 MeV per reaction) and the number of ^{4}He (N_{He}): $N_Q/N_{\mathrm{He}} \sim 30$.

The amount of ^{4}He observed in this work is from 2.1 to 166.8×10^{11} atoms/g, or from 2.1 to 166.8×10^9 atoms per section (where one fifth of the cathode was divided into five sections). Then, the total amount of ^{4}He is estimated to about 10^{13}–10^{14} atoms. From our viewpoint of the TNCF model (see Eq. (1)), the number of tritium (N_t) should be equal to the number of ^{4}He (N_{He}): $N_t = N_{He}$. The experimental value of the total tritium production of 10^{15} tritium atoms given in Section 2.1.1. and that of 10^{13}–10^{14} for ^{4}He atoms observed differ by a factor of an order of two or one:

$$N_t/N_{He})_{exp} = 10^2\text{–}10^1.$$

This discrepancy is consistent with the result [6,7] noticed in the case of the excess heat and ^{4}He (N_Q/N_{He}~30) in the data obtained by Morrey et al. [4]. In this case, it was necessary to assume only a small amount (3%) of produced helium was remained in the cathode. The assumed value of 3% ^{4}He in the cathode in this case (Morrey et al.) seems very close to the necessary value of 1–10% to explain the discrepancy of 10^2–10^1 given above (Chien et al.) in the number of events producing tritium and ^{4}He by the TNCF model.

3. Conclusion

Two fundamental nuclear products, tritium and ^{4}He, expected to exist in the electrolytic system Pd/D/Li, have been observed simultaneously. The data, together with the null result for ^{3}He, is not consistent with the d–d reaction assumed by many based on conventional physics (branching ratios in the parentheses):

$$d + d = t(1.01\ \text{MeV}) + p(3.02\ \text{MeV})\ (1), \quad (3)$$

$$=^3_2\ \text{He}(0.82\ \text{MeV}) + n(2.45\ \text{MeV})\ (1). \quad (4)$$

$$=^4_2\ \text{He}(76.0\ \text{keV}) + \gamma(23.8\ \text{MeV})\ (10^{-6}). \quad (5)$$

In the discussion about the reality of CF phenomenon, it has been usually used a logic where experimental data are criticized using the reactions (3)–(5) as a criterion. If we leave the bias in which only the d–d direct fusion reaction is responsible to the CF phenomenon, we can accept whole of the various experimental facts as a starting point to investigate possible physics of nuclei in solids.

The TNCF model used in this paper to analyze the simultaneous observation of tritium and ^{4}He, including absence of ^{3}He, is a trial in this line of consideration. It seems the model has been applied successfully to give a unified and consistent explanation of various events obtained in the CF phenomenon with a single adjustable parameter n_n in a range of 10^6–10^{12} cm^{-3} and several supplementary premises common to all events. The success of the model will serve as a starting point for complete theory of the cold fusion phenomenon accomplished in the future.

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