Transmutation

Nuclear Transmutation in Cold Fusion Experiments

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Abstract

Nuclear transmutation in chemical and biological systems are investigated with use of Trapped Neutron Catalyzed Fusion Model (TNCF model). In the TNCF model, it is possible to analyze experimental data consistently and quantitatively. We present the investigation of experimental results in cold fusion systems with various materials and methods in this paper.

1. Introduction

There are many experimental results in cold fusion research showing an existence of the nuclear transmutation, i.e. generation of new isotopic species or new elements in the experimental system. The nuclear transmutation has been difficult to understand in conventional physics, but if we take an assumption that the trapped thermal neutrons exist in the sample (TNCF model[1,6]), it is possible to analyze consistently and quantitatively in an accuracy of one or two orders of magnitude. In this paper we will give results of analysis on the various experimental results of the nuclear transmutation.

2. Theoretical Basis of the Analysis

If we take an assumption that the thermal neutron exists in the sample, the following reactions would be expected:

$$n + {}^{A}_{Z}\mathrm{M} = {}^{A+1}_{Z}\mathrm{M}, \quad (1)$$

$${}^{A+1}_{Z}\mathrm{M} = {}^{A+1}_{Z+1}\mathrm{M}' + e^- + \bar{\nu}_e, \quad (2)$$

$$n + {}^{A+1}_{Z}\mathrm{M} = {}^{A+2}_{Z}\mathrm{M}, \quad (3)$$

$${}^{A+2}_{Z}\mathrm{M} = {}^{A+2}_{Z+1}\mathrm{M}' + e^- + \bar{\nu}_e, \quad (4)$$

$$n + {}^{A+1}_{Z+1}\mathrm{M}' = {}^{A+2}_{Z+1}\mathrm{M}', \quad (5)$$

$${}^{A+2}_{Z+1}\mathrm{M}' = {}^{A+2}_{Z+2}\mathrm{M}'' + e^- + \bar{\nu}_e. \quad (6)$$

These reaction formulas begin with a thermal neutron and a nucleus ${}^{A}_{Z}\mathrm{M}$, where ${}^{A}_{Z}\mathrm{M}$ is a nucleus of the sample materials or a minor elements with mass number A and atomic number Z.

The number $d\nu_1(t)$ of the reaction (1) occurring in a short time duration dt at time t is expressed as follows:

$$d\nu_1(t) = 0.35 n_n v_n \rho_0(t) \sigma_1 dt. \quad (7)$$

Where $\rho_0(t)$ is the density of ${}^{A}_{Z}M$, n_n and v_n are the density and the thermal velocity of the trapped thermal neutron and σ_1 is the absorption cross section of the thermal neutron by the nucleus ${}^{A}_{Z}M$. And there is a following relation between $\nu_1(t)$ and $\rho_0(t)$;

$$\rho_0(t) = \rho_0 - \nu_1(t), \quad (8)$$

where ρ_0 is the density of ${}^{A}_{Z}M$ at $t = 0$. From the equation (8) and an integration of the equation (7) with time t, we obtain a relation,

$$\rho_0(t) = \rho_0 e^{-0.35 n_n v_n \sigma_1 t}. \quad (9)$$

So the density $\rho_1(t)$ of the nucleus ${}^{A+1}_{Z}M$ is expressed as follows:

$$\rho_1(t) = \rho_0(1 - e^{-0.35 n_n v_n \sigma_1 t}). \quad (10)$$

Next, in the reaction (3), the number $d\nu_3$ of the reaction (3) in a short time duration dt is given as

$$d\nu_3 = d\rho_3(t) = C\rho_1(t)\sigma_3 dt, \quad (11)$$

where $\rho_3(t)$ is a density of ${}^{A+2}_{Z}M$. In this reaction, the density $\rho_1(t)$ of the nucleus ${}^{A+1}_{Z}M$ changes as follows by the reaction (3):

$$\rho_1(t) = \rho_0(1 - e^{-C\sigma_1}) - \rho_3(t). \quad (12)$$

In these equations C is $0.35 n_n v_n$ and σ_3 is the absorption cross section of the thermal neutron by the nucleus ${}^{A+1}_{Z}M$.

Similarly, we obtain the density $\rho_3(t)$ of the nucleus ${}^{A+2}_{Z}M$:

$$\rho_3(t) = \rho_0[(1 - e^{-C\sigma_3 t}) - \frac{\sigma_3}{\sigma_3 - \sigma_1} \times (e^{-C\sigma_1 t} - e^{-C\sigma_3 t})]. \quad (13)$$

When the half life times of ${}^{A+1}_{Z}M$, ${}^{A+2}_{Z}M$ and ${}^{A+2}_{Z+1}M'$ in the reactions (2), (4) and (6) are very short, the number of β decay to ${}^{A+1}_{Z+1}M'$, ${}^{A+2}_{Z+1}M'$ and ${}^{A+2}_{Z+2}M''$ are equal to ν_1, ν_3 and ν_3, respectively, and densities of them are $\rho_1(t)$, $\rho_3(t)$ and $\rho_3(t)$.

3. Experimental Results and Analysis of the Data

Here we take up some experimental results and investigate them using the method explained above.

1) I.B. Savvatimova et al.[2].

In the glow discharge experiments with D_2 gas (and other gases) and Pd cathode (and other transition metal cathodes), they measured the excess heat and nuclear transmutation of various isotopes and elements with multi-layer cathode. After the discharge of 4 hours,

the sample was sent to mass spectrometry (SIMS) and was analyzed its isotope composition there about 3 $\sim$ 6 months later. Here we take up two data.

1 - a) Decrease of ^{32}S

They detected a decrease of $^{32}_{16}$S from 7 to 2 $\sim$ 3 ppm through the glow discharge with D_2 gas using Pd cathode. We can assume that the density of $^{32}_{16}$S was changed by the reaction (1) only, because $^{31}_{16}$S is not exist (half life is 2.61s), and that $^{31}_{15}$P was not exist in the Pd cathode. From the equation (9), we get a density of the trapped thermal neutron n_n as 2.2 $\times$ 10^{12} cm^{-3} using the values of the average speed of the thermal neutron $v = 2.2 \times 10^5$ cm/s, the absorption cross section $\sigma_1 = 0.53$ barn of n for $^{32}_{16}$S and a duration of experiment $t = 10^7$s ($\simeq$ 4 month).

1 - b) Change of Isotopic Composition of Zr

Before the experiment, few $^{90}_{40}$Zr and $^{91}_{40}$Zr existed in Pd cathode, but after experiment they increased with a ratio of $^{90}_{40}$Zr : $^{91}_{40}$Zr = 57 : 34 (in contrast with 51 : 11 by natural abundance). From the nuclear data, $^{89}_{40}$Zr is unstable and natural abundance of $^{89}_{39}$Y is 100 % , i.e. other Y is unstable. So, we can take there was a few $^{89}_{39}$Y in the Pd cathode and following reactions would occurred:

$$n + {}^{89}_{39}\mathrm{Y} = {}^{90}_{39}\mathrm{Y},$$

$$^{90}_{39}\mathrm{Y} = {}^{90}_{40}\mathrm{Zr} + e^- + \bar{\nu}_e,$$

$$n + {}^{90}_{40}\mathrm{Zr} = {}^{91}_{40}\mathrm{Zr}.$$

The absorption cross sections of neutron for $^{89}_{39}$Y and $^{90}_{40}$Zr are 1.0×10^{-3} and 5.0×10^{-2} barns, respectively. From the equations (12) and (13) and a relation $\rho_1(t) : \rho_3(t) = 57 : 34$, a density of the trapped thermal neutron was calculated as 2.6×10^{13} cm^{-3}.

2) V.A. Romodanov et al.[3].

Romodanov et al. measured a lot of tritium with cylindrical Mo cathode in a glow discharge with D_2 gas. The pressure of the gas was 1 atm in the cylinder and 0.2 atm outside. With a cylindrical cathode of 2.5 cm$\phi\times$ 10 cm with thickness of 5 mm, they measured tritium production of 10^7 s^{-1}. In this case, the temperature of the cathode was very high (up to 3000°C) and we may assume that following reaction would occurred in the whole volume of cathode material:

$$n + d = t\ (6.98\mathrm{kev}) + \gamma\ (6.25\mathrm{Mev}).$$

The fusion cross section of d for n is $\sim 5.5 \times 10^{-4}$ barns and a rate of tritium generation is 10^6 cm^{-3} s^{-1}. The number of the reaction can be expressed by the equation (9). Putting into the formula values obtained or determined in the experiment, we obtain a relation between n_n and n_d ;

$$n_n n_d \sim 3 \times 10^{27}\ \ cm^{-6},$$

where n_d is the density of deuteron. If we assume for the average density of deuterium in the sample $n_d = 10^{20}$ cm^{-3} (10^{18}), then we have the density of the trapped thermal neutron $n_n \sim 3 \times 10^7$ cm^{-3} (3×10^9).

3) M. Okamoto et al.[4].

In an experiment in the series of works on Pd/D + LiOD system conducted hitherto, they determined distributions of Pd, D, Li, Al, and Si atoms in the Pd cathode. As we can see in these figures in Fig.1, densities of those elements changed drastically at near surface of a width $\sim$ 1 μm. Especially, Al decreased to $\sim$ 20 % of the original value and Si increased. We assume following reactions would occurred:

$$n + {}^{27}_{13}\mathrm{Al} = {}^{28}_{13}\mathrm{Al},$$

$${}^{28}_{13}\mathrm{Al} = {}^{28}_{14}\mathrm{Si} + e^- + \bar{\nu}_e,$$

because natural abundance of ${}^{27}_{13}$Al is 100 % and ${}^{28}_{13}$Al is unstable for β decay (half life time is 2.27 m). From the equation (9), we obtain a density of the trapped thermal neutron n_n as 4.9×10^{13} cm^{-3} with the values of the absorption cross section $\sigma_1 = 0.23$ barn of n for ${}^{27}_{13}$Al and a duration of experiment $t = 1.87 \times 10^6$ s.

4) Biotransmutation[5].

Finally we take up the Biotransmutation. From page 25 of kushi's book[5], the elemental transmutation in biological system is considered as " $\sim$ most likely taking place at the cellular level $\sim$ ", and " $\sim$ it was concluded that granted the existence of transmutation $\sim$ ". We investigate three transmutations observed in the biological system Na to Mg, P to S and Mn to Fe.

If we take the same assumption as above that the thermal neutron exist in a living body, we can assume that there occurs following reactions:

$$n + {}^{23}_{11}\mathrm{Na} = {}^{24}_{11}\mathrm{Na} = {}^{24}_{12}\mathrm{Mg} + e^- + \bar{\nu}_e,$$

$$n + {}^{31}_{15}\mathrm{P} = {}^{32}_{15}\mathrm{P} = {}^{32}_{16}\mathrm{S} + e^- + \bar{\nu}_e,$$

$$n + {}^{55}_{25}\mathrm{Mn} = {}^{56}_{25}\mathrm{Mn} = {}^{56}_{26}\mathrm{Fe} + e^- + \bar{\nu}_e,$$

where natural abundance of ${}^{23}_{11}$Na, ${}^{31}_{15}$P and ${}^{55}_{25}$Mn are all 100 % , and all intermediate nuclei produced from them (${}^{24}_{11}$Na, ${}^{32}_{15}$P and ${}^{56}_{25}$Mn) are unstable for β decay. Furthermore, we know the absorption cross sections of ${}^{23}_{11}$Na, ${}^{31}_{15}$P and ${}^{55}_{25}$Mn for thermal neutron are 0.534, 2.2 and 13.3 barn, respectively from data of nuclides. Comparing with the values of the absorption cross section used in the other analyses in this paper, we can recognize that these values are fairly large.

Therefore, if such elements as Na, P and Mn are in a living body with a lot of trapped neutron, it is possible to expect there occurs nuclear transmutations to Mg, S and Fe.

4. Conclusion

We took simple assumptions to investigate the experimental results that there were trapped thermal neutrons with the constance density n_n in the sample and they react with hydrogen isotope in the sample or minor elements, then we can determine the density n_n. The estimated values from other analyses[6] were in a range of $n_n = 10^3 \sim 10^{12}$ cm^{-3}. The results suggest that the TNCF model is one of the most realistic theory. The other three papers[6~8] given in this conference will help to understand the physics of the cold fusion.

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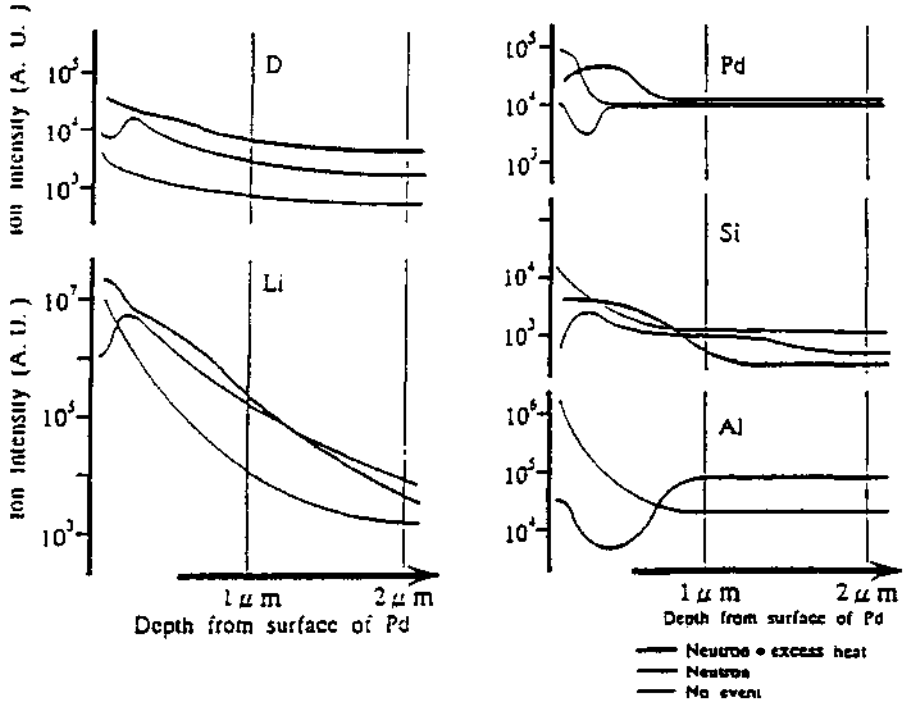

Fig.1 Examples of Depth Profiles for Each Element