# Nuclear Transmutation In a Pd Cathode Observed by Miley et al. Analyzed Using the TNCF Model

*H. Kozima, H. Kudoh,*
*K. Yoshimoto and K. Kaki*
*Department of Physics*
*Faculty of Science*
*Shizuoka University*
*836 Oya, Shizuoka 422, Japan*

## Synopsis

The experimental NAA data of the transmutation products in thin-film Pd layer of 200 μm deposited on 1 mm microspheres (MS) of polystyrene were analyzed using our TNCF model. The observed elements: Al, Cu, V, Ni, Fe, Co, Cr, Zn and Ag, are interpreted as fission products of the trapped neutron catalyzed reactions of Pd.

## 1. Introduction

In the experimental data of the cold fusion phenomenon, several results identifying new elements in the electrodes that appeared to be transmutation products have been obtained. We have analyzed some of them[1~3] using the TNCF model, which has been used to give a consistent interpretation of themany experimental data obtained in the cold fusion research since its discovery. In these analyses, it was pointed out that the nuclear transmutation observed in the experiments should be divided into two categories if the isotope products are to be explained by usual nuclear reactions: a) nuclear transmutation by decay and b) nuclear transmutation by fission. The former is the nuclear transmutation induced by the beta or alpha decays of a nucleus after absorption of a trapped neutron in the material. The latter is that induced by a fission of a nucleus after absorption of a trapped neutron.

The experimental result by Miley et al.[4] is a remarkable one due to the number of elements resulting and their amounts. There are more than ten elements in the list of transmuted nuclei determined by NAA (neutron activation analysis) and by SIMS (secondary ion mass spectroscopy). There are critiques[5~8] of the data analysis given in the paper[4] and we have to be careful to

| Element | Al | Cu | V | Ni | Fe | Co | Cr | Zn | Ag |
|---|---|---|---|---|---|---|---|---|---|
| Yield ($\times 10^{-3}$ $\mu$g/MS) | 233 | 277 | 4.06 | 388 | 153 | 2.18 | 60.4 | 806 | 70.6 |
| No. of atoms ($\times 10^{13}$ /MS) | 520 | 262 | 4.80 | 398 | 165 | 223 | 699 | 742 | 39.4 |

**Table 1**: Elements detected by NAA and their amounts per microsphere.

treat the data given there. We analyzed the experimental results by Miley et al.[4], taking the critiques by Murray[5-8] into consideration and reached our conclusion that the NAA data are valuable for analysis using our model, while the SIMS data are too ambiguous to be analyzed.

Following is our result of analysis of the data on the Pd samples by Miley et al. which shows probable fission of nuclei in the thin film of Pd on the surface of polystyrene microspheres (MS) induced by the trapped thermal neutron in it.

## 2. Experimental results

The electrolytic experiments with cathodes of the packed-bed cell (about 1000 microspheres (MS's)) in a electrolyte 1M LiSO4 + $H_2O$ were performed with nickel, palladium and Pd-Ni multilayer cathodes and titanium electrodes. Voltages across the bed were held at about 2 - 3 V, with several mA of current, giving an electrical input power of approximately 0.06 W. Inlet-outlet thermocouples provided a measure of the temperature increase of the flowing electrolyte. Positive but often very small increases in temperature across the cell ranging from 0.1 to 4°C were observed in all cases.

We take in this analysis only Run #11, where a Pd of 200 μm thin-film was on the polystyrene microsphere. The volume and mass of the film was $7.05 \times 10^{-7}$ cm$^{-3}$ and $8.46 \times 10^{-6}$ g, respectively. The number of Pd atoms in the film was $4.76 \times 10^{16}$.

The analysis of the sample microspheres by NAA after an experiment that lasted 211 hours showed the appearance of elements with yields shown in Table 1.

## 3. Analysis of the data using the TNCF model

According to the TNCF model, as given before[9-11], we assume a quasi-stable existence of the trapped neutrons with a density $n_n$ in the cold fusion material, which is the Pd thin-film for this case. Our supplemental premise demands that the trapped neutrons react with nuclei in the material according to the accepted scheme of nuclear physics with the same cross section for the reaction in the surface layer and with 1 % of it in volume.

To interpret the data given in Table 1, we take only relevant reactions ar, follows (A" = A – A' + 1);

$$n + {}^{A}_{46}\mathrm{Pd} = {}^{A+1}_{46}\mathrm{Pd} \quad (1)$$
$${}^{A+1}_{46}\mathrm{Pd} = {}^{A'}_{13}\mathrm{Al} + {}^{A''}_{33}\mathrm{As}, \quad (2)$$
$$= {}^{A'}_{29}\mathrm{Cu} + {}^{A''}_{17}\mathrm{Cl} \quad (3)$$
$$= {}^{A'}_{23}\mathrm{V} + {}^{A''}_{23}\mathrm{V} \quad (4)$$
$$= {}^{A'}_{28}\mathrm{Ni} + {}^{A''}_{18}\mathrm{Ar} \quad (5)$$
$$= {}^{A'}_{26}\mathrm{Fe} + {}^{A''}_{20}\mathrm{Ca} \quad (6)$$
$$= {}^{A'}_{27}\mathrm{Co} + {}^{A''}_{19}\mathrm{K} \quad (7)$$
$$= {}^{A'}_{24}\mathrm{Cr} + {}^{A''}_{22}\mathrm{Ti} \quad (8)$$
$$= {}^{A'}_{30}\mathrm{Zn} + {}^{A'}_{16}\mathrm{S} \quad (9)$$
$$= {}^{A+1}_{47}\mathrm{Ag} + e^- + \nu_e. \quad (10)$$

The mass number A for the stable isotopes are 102, 104, 105, 106, 108 and 110, with abundances of 0.96, 10.97, 22.33, 27.33, 26.71 and 11.81 %, respectively. If the intermediate nucleus A+1Pd is unstable, i.e. A = 102, 106, 108 and 110, the above fission reactions (2) ~ (10) into two nuclei with mass numbers A' and A" = (A – A' + 1) occur with respective decay constants.

There are some experimental facts showing an acceleration of nuclear reactions in the surface layer of materials, including the trapped neutrons. An example interpreted by acceleration of beta decay was observed for $^{40}$K[12]. Taking into this account, we assume in the following analysis that the reaction constants of the above fission or decay (reactions (2) ~ (10)) are all very short and can be taken as zero in the calculation.

The number of events $N_{A+1}$ in a unit time of the reaction (1) generating the unstable isotopes $^{A+1}$Pd is expressed using the TNCF model as follows;

$$N_{A+1} = 0.35 n_n v_n N_A \Sigma(\sigma_A P_A), \quad (11)$$

where 0.35 $n_n v_n$ is the flow density of the thermal trapped neutron, $n_n$ and $v_n$ are the density and the thermal velocity of the trapped neutrons, respectively, $N_A$ is the initial number of Pd atoms (= 4.76 x $10^{16}$/MS) $\sigma_A$ and $P_A$ are the cross section of thermal neutron absorption for the reaction (1) and the natural abundance ratio of the isotope $^A$Pd, respectively. The cross sections are given in the nuclear physics data book as $\sigma_A$ = 3.363, 3.03 x $10^{-1}$, 8.50, 42.27 x $10^{-1}$ b for A = 102, 106, 108 and 110, respectively. The summation in the relation (11) is over A for unstable isotopes $^{A+1}$Pd.

Using the data for the decreased number of Pd atoms, or total number of generated atoms in Table 1, i.e. $N_{A+1}$ = 3.05 x $10^{16}$, we can determine the adjustable parameter $n_n$ by the relation (11) as follows;

$$n_n = 4.5 \times 10^{12} \text{ cm}^{-3}.$$

We can guess the branching ratios of the reactions (2) ~ (10) if we have the isotope ratio of the generated elements. However, we have only the number of elements as given in the Table 1 and we can calculate only an average of the branching ratios over A and A' from them. Unfortunately, we have no data about the branching ratios for the isotopes or elements as a whole in the published data books. The average branching ratios calculated by the above data are given in Table 2. If we know branching ratios of the reactions (2) ~ (10) for relevant A and A', we can check above treatment based on the TNCF model.

This table shows the same tendency observed in the branching ratio of fission products of a composite nuclei formed by the $n$ + $^{235}$U absorption reaction that the larger the difference of masses of product nuclei is, the larger the branching ratio of the fission reaction is, although this fact is not as yet explained. It is interesting to notice the same strange tendency is seen in the nuclear transmutation by fission as in the cold fusion phenomenon.

| Generated Element | Al | Cu | V | Ni | Fe | Co | Cr | Zn | Ag |
|---|---|---|---|---|---|---|---|---|---|
| Average Branching Ratio (%) | 17 | 8.6 | 0.16 | 13 | 5.4 | 7.3 | 23 | 24 | 13 |

Table 2: Average branching ratios over A' of the reactions (2) ~ (10) generating transmuted nuclei observed in the experiment.

## 4. Discussion

The nuclear reactions investigated after the discovery of radioactivity by Becquerel and artificial nuclear transmutation by Rutherford until ten years ago have mainly been in vacuum or in materials without trapped neutrons. The reactions are between particles with or without electric charge and are fundamentally a two-body problem. Considerable data about nuclear reactions has been accumulating.

However, the nuclear reactions observed in the cold fusion materials are very different from those investigated hitherto as a two-body problem. If we remain in the field of modern physics, which we think is an appropriate approach as far as we can use it effectively, the only factor we have not used effectively is neutrons in the material. Neutron interaction with matter has been investigated as a tool for material analysis and as a method to maintain the fission reaction in atomic piles. Due to the difficulty of controlling the behavior of neutrons, the science of neutrons in materials has been left almost untouched until the discovery of the cold fusion phenomenon.

The cold fusion phenomenon has been a controversial theme of popular science, but not of serious physicists, mainly due to the complexity of events and its secrecy dictated by potential patents. The various experimental data piled up in these ten years, however, show clearly the existence of new scientific facts in materials which include hydrogen isotopes placed in the presence of background neutrons which is estimated at[13] as many as $10^2$ $n/m^2 \cdot s$ for each thermal and epithermal neutron. We hope that our work could be a slow-but-steady step toward the final goal to construct physics of the cold fusion phenomenon

## References


(1) H. Kozima, "Nuclear Transmutation in Cold Fusion," *Symposium on the Nuclear Transmutation in Solids* (June 1997, Iwate Univ., Morioka, Japan) p.82 (1997); *Cold Fusion* **23**, 54 (1997).

(2) H. Kozima, K. Yoshimoto and K. Kaki, "A Qualitative Explanation of Nuclear Transmutation as a Whole," *Cold Fusion* **24**, 4 (1997).

(3) H. Kozima, H. Kudoh and K. Yoshimoto, "Nuclear Transmutation by Fission in Cold Fusion Experiment Analyzed using the TNCF Model," *Cold Fusion* **25**, 34 (1998).

(4) G.H. Miley, G. Name, M.J. Williams, J.A. Patterson, J. Nix, D. Cravens and H. Hora, "Quantitative Observation of Transmutation Products Occurring in Thin-Film Coated Microspheres during Electrolysis," Progress *in New Hydrogen Energy (Proc. ICCF6)* (Oct. 1996, Hokkaido, Japan) p.629 (1996). And also *Cold Fusion* **20**, 71 (1996).

(5) R.T. Murray, "A Critique of George Miley's Recent Preprints (1)," *Cold Fusion* **20**, 59 (1997).

(6) R.T. Murray, "A Critique of George Miley's Recent Preprints (2)," *Cold Fusion* **20**, 66 (1997).

(7) R.T. Murray, "A Critique of George Miley's Recent Preprints (3)," *Cold Fusion* **20**, 68 (1997).

(8) R.T. Murray, "A Critique of George Miley's Recent Preprints (4)," *Cold Fusion* **20**, 69 (1997).

(9) H. Kozima, "The TNCF Model -A Phenomenological Model for the Cold Fusion Phenomenon," *J. New Energy* **2-2**, 43 (1997): *Cold Fusion* **23**, 18 (1997).

(10) H. Kozima, K. Kaki and M. Ohta, "Anomalous Phenomenon in Solids Described by the TNCF Model," *Fusion Technology* **33**, 52 (1998).

(11) H. Kozima, "How Cold Fusion Occurs (2)," *Rep. Fac. Science, Shizuoka Univ.* **32**, 1 (1998).

(12) H. Kozima, K. Arai and M. Fujii, "Analysis of Tritium and Heat Generation in Ni/H/K System by Notoya et al.," *Elemental Energy (Cold Fusion)* **26**, 20 (1998).

(13) J.M. Carpenter, "Cold fusion: What's going on?" *Nature* **338**, 711 (1989).