Nuclear Transmutation and Excess Heat In Ni Cathode Observed by Miley et al. Analyzed Using the TNCF Model

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Synopsis

The experimental NAA and SIMS data of the transmutation products and the excess heat in thin-film Ni layer of 6.5 x 10^{-2} μm deposited on 1 mm microspheres (MS) of polystyrene were analyzed using our TNCF model. The observed elements, Cr, Fe, Cu, Zn and Ag by NAA and others by SIMS including Mn, and the excess heat of 0.5 W from 1000 MS's are interpreted consistently as fission products of trapped neutron catalyzed reactions of Ni.

1. Introduction

As was discussed in the previous paper[1], several reports identifying new elements found in the Patterson Power Cell electrodes appear to be transmutation products. Here we will analyze the resulting experimental date using our TNCF model. This model has been used successfully to provide a consistent interpretation of many experimental data of the various events obtained in cold fusion research since its discovery. In these analyses, it has been pointed out that the nuclear transmutation (NT) observed in experiments should be divided into two categories if the products isotopes are going to be explained by usual nuclear reactions; a) nuclear transmutation by decay (NTD) and b) nuclear transmutation by fission (NTF). The former is the nuclear transmutation induced by the beta or alpha decays of a nucleus after absorption of a neutron trapped in the material. The latter is that induced by a fission of a nucleus after absorption of a trapped neutron.

The experimental results reported

Element	$^{52}_{24}$Cr	$^{53}_{24}$Cr	$^{54}_{24}$Cr	$^{55}_{25}$Mn	$^{54}_{26}$Fe	$^{56}_{26}$Fe	$^{57}_{26}$Fe	$^{59}_{27}$Co	$^{63}_{29}$Cu
No. of atoms ($\times 10^{15}$/1000MS)	106	13.5	2.53	80.0	15.0	227	13.1	1.87	112

Element	$^{65}_{29}$Cu	$^{64}_{30}$Zn	$^{66}_{30}$Zn	$^{67}_{30}$Zn	$^{68}_{30}$Zn	$^{70}_{30}$Zn	$^{107}_{47}$Ag	$^{109}_{47}$Ag	
No. of atoms ($\times 10^{15}$/1000MS)	48.2	15.3	8.44	2.05	12.5	1.22	68.8	54.7	

Table 1: Elements detected by NAA (and SIMS) and their amounts per 103 MS's.

by Miley et al.[5] are remarkable in view of the number of elements and their amounts, in addition to the data[6] analyzed in our previous paper[1]. There are more than eighty isotopes in the list of transmuted nuclei determined by NAA (neutron activation analysis) and by SIMS (secondary ion mass spectroscopy). There are critiques[7~10] by R.T. Murray of the data analysis given in the papers[5,6] and we have to be careful to treat the data given there. We analyzed the experimental results by Miley et al.[5] in this paper taking the critiques[7~10] into our consideration and reached our conclusion that the isotopes determined by NAA were consistent with our model, but those determined by SIMS, except Mn, are not.

Following is the result of our analysis of the data obtained by NAA in the Ni samples by Miley et al.[5] which shows probable decay of nuclei in the thin film of Ni on the surface of polystyrene microspheres (MS) induced by the trapped thermal neutrons in it.

2. Experimental results

The electrolysis in this experiment was performed with an electrolytic solution of 1M $Li_2SO_4 + H_2O$, with a cathode composed of 1000 MS's coated by Ni layer. The voltage and current used in the electrolysis were 2 ~ 3 V and 2 ~ 3 mA, which gives current density at the surface of MS, $i = 0.057 \sim 0.085$ mA/cm^2. The experiment lasted 310 h = 1.12 x 10^6 s.

This value of the current density is very small compared with usually used values in experiments oriented to generate excess heat. The value i and the duration of the experiment legitimate our neglect of the influence of the surface layer of Li or $NiLi_x$ alloy in the analysis given in the next section.

The excess heat was 0.5 ± 0.4 W from 1000 MS's.

The NT products were determined by NAA and SIMS (for $^{55}_{25}$Mn) for 1000 MS's (using only 10 MS's for analysis). A part of the experimental result is reproduced in Table 1.

3. Analysis of the data using the TNCF model

According to basis for the TNCF model[11~13] we assume the quasi-stable existence of the trapped neutrons with a density n_n in the cold fusion material, and in the Pd thin-film for the previous case[1]. One part of our premise demands that the trapped neutrons react with nuclei in the material according to usual scheme of nuclear physics with the same cross section for the reaction in the surface layer and with 1% of it in volume. The number of the reaction between the trapped neutron n and a nucleus $^{A}_{Z}M\,P_f$ in unit time is expressed as follows with a stability factor ξ (=1 in the surface layer and = 0.01 in volume):

$$P_f = 0.35 n_n v_n n_M V \sigma_{nM} \xi, \qquad (1)$$

where $0.35 n_n v_n$ is the flow density of the neutrons per unit area and time, n_M is the density of the nucleus, V is the volume where the reaction occurs, σ_{nM} is the cross section of the reaction.

We assume a natural abundance of isotopes of nickel, i.e. the abundance of the isotopes with mass numbers 58, 60, 61, 62 and 64 are 67.88, 26.23, 1.19, 3.66 and 1.08 %, respectively. Due to the thinness of the Ni layer on the MS we assume the stability factor ξ as 1 in the following analysis according to our premises[11~13].

The trigger reactions we assume in the system where Miley et al. observed NT[5] are written down as follows:

$$n + {}^{58}_{28}\mathrm{Ni} = {}^{59}_{28}\mathrm{Ni} \qquad (2)$$
$$n + {}^{60}_{28}\mathrm{Ni} = {}^{61}_{28}\mathrm{Ni} \qquad (3)$$
$$n + {}^{61}_{28}\mathrm{Ni} = {}^{62}_{28}\mathrm{Ni} \qquad (4)$$
$$n + {}^{62}_{28}\mathrm{Ni} = {}^{63}_{28}\mathrm{Ni} \qquad (5)$$
$$n + {}^{64}_{28}\mathrm{Ni} = {}^{65}_{28}\mathrm{Ni} \qquad (6)$$

The fusion cross sections of these reactions for thermal neutrons is 4.6, 2.9, 2.5, 15 and 1.8 b, respectively. Because the fusion products ${}^{61}_{28}$Ni and ${}^{62}_{28}$Ni are stable, we discard them from our analysis, although there remains the possibility of their destabilization by interaction with the trapped neutrons.

Then, the fusion product ${}^{59}_{28}$Ni, ${}^{63}_{28}$Ni, ${}^{65}_{28}$Ni could be the candidates responsible for the NT observed in the experiment. To explain the product of NT listed in Table 1, we find out in data tables following reactions relevant with them:

$${}^{59}_{28}\mathrm{Ni} = {}^{59}_{27}\mathrm{Co} - e^-, \qquad (7)$$
$$= {}^{58}_{27}\mathrm{Co}^* + p + 0.401\ \mathrm{MeV}, \qquad (8)$$
$$= {}^{55}_{26}\mathrm{Fe} + {}^{4}_{2}\mathrm{He} + 2.90\ \mathrm{MeV}, \qquad (9)$$
$${}^{63}_{28}\mathrm{Ni} = {}^{63}_{29}\mathrm{Cu} + e^- + \nu_e + 65\ \mathrm{keV}, \qquad (10)$$
$${}^{65}_{28}\mathrm{Ni} = {}^{65}_{29}\mathrm{Cu} + e^- + \nu_e + 2.14\ \mathrm{MeV} \qquad (11)$$

The electron capture (7) occurs with time constant 7.6 x 10^4 y. The proton emission (8) and the alpha decay (9) are not known yet in nuclear physics and we have no data of its time constant. The beta decays (10) and (11) have time constants of about 10^2 y and 2.517 h, respectively.

The products of the reactions (8) and (9) transmute according following reactions:

$${}^{58}_{27}\mathrm{Co}^* = {}^{58}_{27}\mathrm{Co} + \gamma = {}^{58}_{26}\mathrm{Fe} - e^- + \gamma, \qquad (12)$$
$$n + {}^{58}_{27}\mathrm{Co}^* = {}^{59}_{27}\mathrm{Co}, \qquad (13)$$
$${}^{55}_{26}\mathrm{Fe} = {}^{55}_{25}\mathrm{Mn} - e^-, \qquad (14)$$
$$n + {}^{55}_{26}\mathrm{Fe} = {}^{56}_{26}\mathrm{Fe}, \qquad (15)$$
$${}^{56}_{26}\mathrm{Fe} = {}^{55}_{25}\mathrm{Mn} + p + 1.01\ \mathrm{MeV}, \qquad (16)$$
$$= {}^{52}_{24}\mathrm{Cr} + {}^{4}_{2}\mathrm{He} + 3.58\ \mathrm{MeV}, \qquad (17)$$

The absorption cross sections of the reactions (13) and (15) are 1.4 x 10^5 and 13 b, respectively, and the time constant of the gamma emission (12) is 9.1 h.

Using these data on the nuclear reactions (2), (5) and (6) relevant to the experimental data on NT in Ni, we can determine production rates N_A of ${}^{59}_{28}$Ni, ${}^{63}_{28}$Ni and ${}^{65}_{28}$Ni as follows:

$$(N_{59} : N_{63} : N_{65}) = 1 : 0.17 : 5.73 \times 10^{-3}. \qquad (18)$$

This ratio is compared with the experimental values assuming following relation. The isotope ${}^{59}_{28}$Ni generates isotopes ${}^{59}_{27}$Co, ${}^{56}{}_{2}$6Fe, ^{55}25Mn and ${}^{52}_{24}$Cr according to the reactions (7) and (13), (15), (14) and (16), and (17), respectively. If we assume the long or unknown time constants of these reactions, we can calculate the number of

$^{59}_{28}$Ni by a sum of these isotopes. The amounts of $^{63}_{28}$Ni and $^{65}_{28}$Ni are taken to be those of $^{63}_{29}$Cu and Cu, respectively, by the reactions (10) and (11), with the same assumption about the time constant. Then, the experimental ratio to be compared with the ratio (~~19~~) 18 is given as follows:

$$(N_{59} : N_{63} : N_{65})_{exp} = 1 : 0.27 : 0.12. \quad (19)$$

Comparison of the relation between (18) and (19) gives us qualitative coincidence of the theoretical and experimental data for the production rates of isotopes in the Ni surface layer on MS and supports the TNCF model for the cold fusion phenomenon.

The relation (1) gives us the density of the trapped neutrons n_n by the experimental values N_A of $^{50}_{28}$Ni, $^{63}_{28}$Ni and $^{65}_{28}$Ni in our regime, respectively as follows:

$$n_n = 7.6 \times 10^{10}\ \text{cm}^{-3} \quad (20)$$
$$n_n = 1.2 \times 10^{11}\ \text{cm}^{-3} \quad (21)$$
$$n_n = 1.7 \times 10^{12}\ \text{cm}^{-3} \quad (22)$$

The third value 1.7×10^{12} cm^{-3} is based on the most reliable experimental value of the amount $^{65}_{29}$Cu. The first and the second are based on the assumption that the decay times in relevant reactions are mostly shortened by the interaction of nuclei and the trapped neutrons, and the values n_n are underestimated.

Another comparison is possible for the excess heat. The reactions used to interpret the NT data give the excess heat on the assumption that the liberated energy in the nuclear reactions is all thermalized and measured. Then the excess heat is fundamentally given by the energy generated in the reactions (9) and (11) and calculated as follows:

$$Q_{th} = (2.55 \times 10^{17} \times 2.90 + 4.82 \times 10^{16} \times 2.14)\ \text{MeV} \times 1.60 \times 10^{-13}\ \text{(J/MeV)} \quad (23)$$
$$= 1.35 \times 10^{5}\ \text{J}. \quad (24)$$

Inclusion of reactions (10), (16) and (17) did change the above value only by a factor of 2.

Then the excess power is $P_{th} = Q_{th}/1.12 \times 10^6\ \text{s} = 0.12$ W:

$$P_{th} = 0.12\ \text{W}.$$

This value is compared with the experimental value:

$$P_{ex} = 0.5 \pm 0.4\ \text{W}.$$

In our experience, Q_{th} determined by the number of events for nuclear products is several times smaller than Q_{ex} determined by experiment. Considering the uncertainty of the experimental value (0.5 ± 0.4 W) and this general tendency obtained in the data analysis, we could conclude that the coincidence of the data analyses of NT and the excess heat given above is fairly good.

4. Discussion

The above analysis of the experimental data of the nuclear transmutation and the excess heat in an electrolytic system — the so-called the Patterson Power Cell with polystyrene microspheres with a Ni film on the surface — gives us a consistent interpretation using the TNCF model, except for the production of Ag, which was measured by NAA, which calls for an increase of the mass number by more than 45 in the system. Thus, the results given in the previous analysis of Pd cathode by NT_F and given in this analysis of Ni cathode by NT_D show us 1) the existence of the trapped neutrons in the samples and 2) the induction of nuclear fission and nuclear decay of unstable nuclei formed as a result of neutron absorption by nuclei in the metal layer on the surface of microspheres.

There remain, however, several unexplained facts about the Ag detected by NAA and other new nuclei[5] detected by SIMS. We have to be modest in the treatment of experimental data as discussed by Murray[7~10], although the analysis of selected data given in this paper is satisfactory to provide a consistent understanding of the NT aspect of the cold fusion phenomenon.

The existence of trapped thermal neutrons in solids has been supported by the consistent analysis given in this and our previous papers[11~13], where we examined about 50 experimental data from representative events of the cold fusion phenomenon, including the excess heat, tritium, helium, and neutrons. The parameter n_n, interpreted as a density of the trapped neutrons, has been determined in these analyses to be $10^8 \sim 10^{13}$ cm^{-3}. The consistency in the interpretation of the cold fusion phenomenon and the adequacy of the value determined for n_n provides evidence of the validity of the TNCF model. There is, in our opinion, the physics of "neutrons in solids" in the TNCF model.

One of the most remarkable processes revealed by NT, an aspect of the cold fusion phenomenon, is the destabilization of nuclei interacting with trapped neutrons. This phase of the physics of neutrons in solids is revealed, as shown in this and a previous paper1 for instance, by the appearance of isotopes, e.g. ^{59}Co and ^{63}Cu in NT$_D$, which are generated by the very slow decay processes in the usual condition (in a vacuum), and by isotopes, e.g. Al and Cr in NT$_F$ generated only by fission with large (more than 50 MeV) threshold energy in vacuum.

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