Nuclear Fission in the Cold Fusion Phenomenon

A Qualitative Explanation of Nuclear Transmutation as a Whole

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Synopsis

The nuclear transmutation with large shifts of mass and atomic numbers in the cold fusion phenomenon is explained qualitatively by the TNCF model. The transmutation product is explained as a result of a nuclear fission of a nucleus in the material containing the trapped neutrons which destabilize the nucleus. Thus, a consistent explanation for the cold fusion phenomenon as a whole is given using the TNCF model.

1.Introduction

In the more than 8 years since the discovery of the cold fusion phenomenon in 1989, very many experiments have been performed, investigating the excess heat and any nuclear products generated by reactions in the cold fusion materials. In the first stage of the research in this new field, the guiding principle had been the direct reactions of two deuterons assumed by an extrapolation of reactions in the plasma fusion and in the muon-catalyzed fusion. The main targets of the experiments were, therefore, the excess heat, neutrons, and tritium. In the progress of the research it has been shown that there are more abundant products in the phenomenon than those first supposed, including not only ^{4}He, which is a probable nuclear product of the deuterium reaction, but also many isotopes and elements that had not existed before the experiment, which are outside a scope of the deuterium reactions (the nuclear transmutation, NT).

At first, the researchers who had noticed the appearance of those alien nuclei in the product of their cold fusion experiments had been bewildered and hesitated to publish their results. Earlier information of the nuclear transmutation with a large shift of mass (A) and atomic (Z) numbers (say 'NT with a fission' or NTF, because the product seems to be only understandable by a nuclear fission in the material) was communicated through private conversation among researchers at conferences and workshops. Piling up the same kind of data, researchers had confidence in their results and began to present their data at conferences and workshops and to publish them in periodicals.

One of the present authors (H.K.) had proposed the TNCF model[1] for the cold fusion phenomenon which had succeeded in explaining the various data consistently with a single adjustable parameter n_n, except NTF, which seemed to indicate the occurrence of nuclear fission in solids. The experience in nuclear physics tells us that the nuclear fission of a nucleus with a medium mass number by neutron absorption can be achieved only when the energy of the neutron is more than several tens MeV. This fact made us exclude those NT reports from our object of analysis until now.

The success in the analysis of cold fusion data by the TNCF model (except NTF) forced us finally to analyze the hitherto excluded data and to check the applicability of the model to a the wider range of events. In this paper, therefore, we investigate NT in general by the TNCF model and show a qualitative explanation of NTF due to a de-stabilization of lattice nuclei (nuclei consisting the lattice) by the trapped neutron and to a nuclear fission of a nucleus.

2.TNCF Model and NT with Small Shifts of *A* and *Z*

The TNCF model[1], proposed in 1993 at ICCF4, has been used to analyze not only the excess heat and nuclear products (t, ^{4}He, γ, n,......) data, but also transmutation products with small shifts of mass (A) and atoniic (Z) numbers (say 'NT with a decay' or NTD, because the product was explained by a β or an α decay of a nucleus generated in a fusion of the trapped neutron and a nucleus in the material). The data of NTD analyzed with success were those by R.T. Bush[2], R.T. Bush and D.R. Eagleton[3] , M. Okamoto et al.[4], I. Savvatimova et al.[5], P.O. Passell[6], H. Yamada et al.[7] and Y. Oya et al.[8]. (There are some data in these papers showing NTF which were left untouched in the previous analyses.) The results of our analyses gave a consistent explanation of NTD together with the excess heat and/or other events by a single adjustable parameter n_n and were published in individual papers[9~13] and also in summarized form[14,15].

The parameter n_n determined by the experimental data in these analyses was $5 \times 10^{10} \sim 10^{11}$ cm^{-3} (Bush)[14], 1.1×10^9 cm^{-3} (Bush and Eagleton)[9], $\sim 10^{10}$ cm^{-3} (Okamoto et al.)[10], 1.9×10^8 cm^{-3} (Savvatimova et aJ.)[11], 6.1×10^9 cm^{-3}, (T.O. Passell)[12], 2×10^{12} cm^{-3} (Yamada et al.)[13] and 3×10^9 cm^{-3} (Oya et al.)[14]. Details of the analyses were given in our previous papers referred to above.

The fundamental reactions used in the analysis of NTD are those between the trapped neutron and nuclei in the material followed by a beta or an alpha decay:

$$n + {}^{23}\mathrm{Na} = {}^{24}\mathrm{Na} + e^- + \nu_e \tag{1}$$

$$n + {}^{27}\mathrm{Al} = {}^{28}\mathrm{Al} = {}^{28}\mathrm{Si} + e^- + \nu_e, \tag{2}$$

$$n + {}^{39}\mathrm{K} = {}^{40}\mathrm{K} = {}^{40}\mathrm{Ca} + e^- + \nu_e, \tag{3}$$

$$n + {}^{85}\mathrm{Rb} = {}^{86}\mathrm{Rb} = {}^{86}\mathrm{Sr} + e- + \nu_e, \tag{4}$$

$$n + {}^{106}\mathrm{Pd} = {}^{107}\mathrm{Pd} = {}^{107}\mathrm{Ag} + e- + \nu_e, \tag{5}$$

$$n + {}^{16}\mathrm{O} = {}^{17}\mathrm{O} = {}^{13}\mathrm{C} + {}^{4}\mathrm{He}. \tag{6}$$

3. Nuclear Transmutation with large shifts of *A* and *Z*

As was briefly explained in the introduction, there are many data showing generation of transmutation products with large shifts of *A* and *Z* in cold fusion experiments, including those cited in Section 2 (where NTD was analyzed using the TNCF model).

First of all, we explain in this Section some recent typical data of NTF and then give their qualitative explanation using the TNCF model. The examples introduced here are four papers by Mizuno et al., Ohmori et al., Notoya et al. and Miley et al.

1) T. Mizuno et al.[17]

Mizuno et al. at Hokkaido University, Japan observed NT in the surface layer (thickness $t \leq 2$ µm) induced by electrolysis in Pd/D/Li system. The identification of isotopes was performed by SIMS (Secondary Ion Mass Spectrometry), AES (Auger Electron Spectroscopy), EPMA and EDX. Many elements including Pt, Cu, Cr, Pd, Zn, Br, Xe, Cd, Hf, Re, Ir, Pb and Hg were observed and showed a shift of the isotope ratios from natural ones. In a previous analysis, we took up only one data of ^{52}Cr: the isotope ratio of ^{52}Cr observed in the surface layer showed a reduction from 83.8% (the natural abundance) to 50% through an electrolysis of 30 days. The reduction was explained by a reaction like (1) given above in the surface layer.

2) T. Ohmori et al.[18]

In the electrolysis with a gold electrode and an electrolyte Na_2SO_4 (or K_2SO_4, K_2CO_3, KOH) in H_2O for a week, a notable amount of iron atoms in the range of 1.0×10^{16} to 1.8×10^{17} atoms/cm^2 are detected at surface, together with the generation of a certain amount of excess energy. The isotopic abundance of iron atoms, measured at the top surface of a gold electrode, are 6.5, 77.5 and 14.5% for ^{54}Fe, ^{56}Fe and ^{57}Fe, respectively, and are obviously different from the natural abundance. The content of ^{57}Fe tends to increase up to 25% in the more inner layers of the electrode.

3) R. Notoya et al.[19]

In a series of experiments with Ni cathode in H_2O (and D_2O) solutions of electrolytes K_2CO_3 (and Li_2CO_3, Na_2CO_3, Rb_2SO_4, Cs_2SO_4), Notoya et al. at Hokkaido University observed NT and positron generation in the system by oserving the gamma ray spectrum. In addition to the production of ^{40}K, ^{56}Co, ^{64}Cu and ^{65}Zn, they detected a 0.511 MeV line due to the positron annihilation.

In the case of a porous Ni cathode with a dimension of 1.0 x 0.5 x 0.1 cm and with a density 58% of Ni metal and a electrolytic solution of 0.5 M K_2CO_3 + H_2O (20 to 30 ml as a whole), they observed an increase 100% of ^{40}K after 24 hours electrolysis and the annihilation gamma ray at 0.511 MeV. The increase of ^{40}K by 100% in the solution corresponds to a generation of 3.0×10^{16} ^{40}K nuclei.

4) Miley et al.[20]

In the experiment where nuclear transmutation products were measured, the authors used the Dr. Patterson's coated microspheres as a cathode to generate excess heat with a high yield and good reproducibility. They achieved a quantitative measurement of transmuted products by using a unique thin-film electrode configuration to isolate the transmutation region, plus measurements based on neutron activation analysis. Results from a thin-film (500-3000Å) Pd and Pd/Ni coating on 1-mm microspheres in a packed-bed type cell with 1-molar $LiSO_4 - H_2O$ electrolyte were reported. The transmutation products in all cases characteristically divide into four major groups with atomic number $Z \cong 6$ - 18; 22 - 35; 44 - 54; 75 - 85. Yields of ~ 1 mg of key elements were obtained in a cell containing ~ 1000 microspheres (~1/2 cc). In several cases over 40 atom % of the metal film consisted of these products after two weeks' operation.

As mentioned in each brief explanation of the above papers, those experimental data are typical examples out of many data showing the nuclear transmutation with large shifts of A and Z (NTF). From our point of view these experimental data should be explained using usual quantum mechanics. Then, these data might be accepted as results of probing the materials including hydrogen isotopes using the cold fusion phenomenon. A possible explanation could be given as follows.

As relevant nuclear reactions in NTF we may take up a fission reaction and the like with emission of several (say v) neutrons induced by an energetic or thermal neutron (and/or an energetic charged particle generated by a cold fusion reaction):

$$n(\varepsilon)+{}^{A}_{Z}M={}^{A-A'+1}_{Z-Z'}M+{}^{A'}_{Z'}M \text{.......}(7)$$

$$n(\varepsilon)+{}^{A}_{Z}M={}_{Z-Z'}M'+{}^{A''}_{Z'}M''+\upsilon n,$$

$$(A+1=A'+A''+\upsilon)\text{..............}(8)$$

Usually, the threshold energy of the above fission reaction for an element with a mass number around 100 or more amounts to about 50 MeV in a vacuum. In cold fusion, however, the possible maximum energy of a particle generated by a reaction using the TNCF model is that of the neutron generated by a breeding reaction

$$t(\varepsilon)+d={}^{4}\mathrm{He}\,(3.5\mathrm{MeV})+n\,(14.1\mathrm{MeV}),$$

and is 14.1 MeV. Therefore, the experimental result showing NTF should be an evidence of a fission reaction occurring in materials with a lower threshold energy than in a vacuum (sometimes that even by a thermal neutron).

Then, there is a question how the lowering of the threshold energy of the nuclear fission occurs. A possible explanation of this peculiar behavior might be explained by a neutron-lattice nuclei interaction in the crystal containing the trapped neutrons. It is conceivable that stabilization of the trapped neutron reflects, inversely, on the destabilization of lattice nuclei.

A stable nucleus in a crystal lattice containing the trapped neutron can stabilize the neutron through the strong interaction between the neutron and lattice nuclei as assumed in the TNCF model and supported by the success of the model in the analysis of many experimental data[15,16]. In this process of neutron stabilization the lattice nuclei, which are stable usually, are destabilized by the same interaction, inversely. Therefore, the lattice nuclei in the cold fusion materials, in which are many trapped neutrons, decay by fission more easily than those in a vacuum. From experimental data, we can imagine that the threshold energy of those elements like Ni, Pd and Au, where observed NTF, is lowered down to few MeV or less, which is possibly the energy had by particles where are generated in the trigger and breeding reactions in the TNCF model.

We can cite an example of energy balance in the fission of a gold isotope ${}^{198}_{79}$Au into iron and iodine in a vacuum (though we don't know the branching ratio of this channel):

$$n + {}^{197}_{79}\mathrm{Au} \rightarrow {}^{57}_{20}\mathrm{Fe} + {}^{141}_{53}\mathrm{I} + Q, \qquad (9)$$

with $Q = 97.9$ MeV. Preliminary analysis by the TNCF model showed $n_n \sim 10^{11}$ cm^{-3} in this case assuming the branching ratio equals 1. This shows that the threshold energy for the above reaction in an appropriate material becomes very small (even zero) making this channel predominant if it is positive and large and the branching ratio is small.

The frequent observationl[17~20] of NT products with large shifts of *A* and *Z* in experiments might be another evidence of the existence of the trapped neutrons assumed in the TNCF model, which has successfully explained other events than NTF in the cold fusion phenomenon. A quantitative treatment of this investigation described above will be given elsewhere.

4. Conclusion

The cold fusion phenomenon, discovered in 1989 by Fleischmann et al.[21], has been confirmed in its essential parts experimentally and has since been considerably enlarged upon. Now the phenomenon is considered as a part of a new science composed of both the generation of excess heat and of tritium. ^{4}He, γray and neutron, and NT (nuclear transmutation), with small and large shifts of *A* and *Z*.

The variety of events are difficult to understand as a whole. In this stage of the research it is, as usual, helpful to use a phenomenological point of view in order to have a solid stand point, even if it is based on some assumptions which are difficult to explain using the existing concepts of science. Many examples of excellent models have shown their value in history, with one of the most famous models being the Bohr model of the hydrogen atom.

We do not, however, demand permanent value for the TNCF model for the cold fusion phenomenon, although it has been useful in providing a unified explanation for the various events in it[22,23]. The premises used in the model, like the neutron band and the neutron affinity of lattice nuclei, should be verified using the fundamental principles of the physics. Perhaps using quantum mechanics will help. However, we also have to remember that there are several experimental facts inconsistent with the TNCF model, e.g. the scarcity of γrays observed and the lack of expected simultaneity of several events in some experiments. These gaps should be closed via both experiment and theory. A dialogue between theorists and experimentists should result in the development of a new science which will explain the cold fusion phenomenon.

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