ON COLD FUSION IN A NI-H SYSTEM

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The problem of excess heat production in a Ni-H system was investigated according to the Trapped Neutron Catalyzed Fusion model (TNCF model). Explanations of experimentally observed amount of excess energy are given.

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1. Introduction

The cold fusion phenomena in Pd-D and Ti-D systems discovered in 1989 (1,2) have been attracting world-wide strong attention as a promising energy source, should it be realized. Because of the complex nature of the phenomena, however, there have been controversies as to the reliability of the experimental results, which show astonishing effects not observed or noticed before.

Recently, a discovery of excess heat generation in Ni-H system was reported (3). This news shows, as we have already pointed out (4–6), that the cold fusion phenomena occurs not only in Pd-D and Ti-D systems but also in some ceramics and other metals containing a lot of hydrogen and deuterium. According to the TNCF model, we will calculate some parameters pertinent to the cold fusion in Ni metal and show the reality of the experimental results.

2. Model Calculation

As is explained in the previous papers (4–6), the first factor of the TNCF model is, as the name shows, the trapping of low-energy neutrons in the metal containing a lot of protons (deuterons). And if there are trapped neutrons, the starting reaction is the following, between a trapped neutron and an occluded proton (we will consider only the case of metal-H system):

$$n + p = d\ (1.33\ \text{keV}) + \gamma\ (2.22\ \text{MeV}) \qquad (1)$$

If this reaction occurs between the trapped neutrons and the occluded (or included) hydrogens, the main energy owned by the emitted photon (2.22 MeV) will traverse the matrix material. According to the TRIUMF Kinematics Handbook (Table VII-6), the mass attenuation length for the 2.22 MeV photon is almost the same as for the 6.25 MeV photon calculated before (5) for materials with the atomic number Z larger than 25. From the data given in the previous paper (5) (fig. 2 and table 3), we obtain the attenuation length of the 2.22 MeV photon in Ni metal as 3.4 cm.

This value shows that the excess heat generated by cold fusion can be observed in a Ni metal sample, which includes a lot of hydrogen, if it has a linear dimension of the order of a few centimeters (size effect).

The deuteron with energy 1.33 keV generated in reaction 1 can propagate without energy loss (channeling) along a line through interstitial sites (OHS line) where there are absorbed protons. The deuteron collides with one of these protons to fuse into ^{3}He:

$$d + p = {}^3\text{He}\ (5.35\ \text{keV}) + \gamma\ (5.59\ \text{MeV}) \qquad (2)$$

The photon generated in this reaction dissipates almost completely in the sample we are now considering. The ^{3}He, on the other hand, can propagate along an OHS line and collide with a proton on the line. The accelerated proton will fuse finally with a deuteron in the sample generated in reaction 1 and rest on an interstitial site.

On the other hand, if the deuteron generated in reaction 1 loses energy before making fusion reaction 2, the deuteron stays in an interstitial site and may be collided with a neutron to fuse into a triton:

$$n + d = t\ (6.98\ \text{keV}) + \gamma\ (6.25\ \text{MeV}) \qquad (3)$$

The photon will decay in the sample and the triton can propagate along an OHS line to fuse with another proton:

$$t + p = {}^4\text{He}\ (0.09\ \text{MeV}) + \gamma\ (19.92\ \text{MeV}) \qquad (4)$$

Thus, in an optimum situation, as in the situation considered in a previous paper (6), the initial fusion reaction 1 between a trapped neutron and a proton induces sequential reactions (reaction 2) to produce energy to heat the matrix. In the case of a material including protons, there are no process breeding neutrons, and it is expected that the neutron burst and thermal explosion will be different from the case of the deuteron previously investigated (6).

To realize reaction 1, it is necessary to fulfill certain conditions: First of all, a lot of protons must exist in the sample. Secondly, the neutrons must be "trapped" in the sample by particular mechanisms to stay there long enough to realize the fusion reaction 1. The postulated mechanisms of neutron trapping are:

1. total reflection by the boundary of regions with different densities of the proton,
2. Bragg reflection by ordered lattice of included protons, and
3. neutron Moessbauer effect (7).

In the case of a nucleus with a medium mass number, like Ti, Ni and Pd isotopes, a neutron is usually absorbed to form an excited state of another isotope. The isotope may emit a neutron or a photon to attain the final state. In this way, the matrix nuclei work as a neutron reservoir to trap neutrons (neutron Moessbauer effect).

In one experiment (3), the specific protocols for loading the hydrogen into nickel made, in our opinion, the sample inhomogeneous and appropriate for the trapping of neutrons with these mechanisms.

As other mechanisms to localize neutrons, it is possible to consider many body effects, such as inducing Anderson localization of electrons in random lattices.

Neglecting all nuclear reactions between matrix nuclei and elementary particles, we may assume ten occurrences of reaction 2 following the initial reaction 1. Then, 10^{12} neutrons per second in the sample produce an energy corresponding to 50 W of heat.

Inclusion of the following d-d reaction cycle will make the necessary number of the initial neutrons several orders of magnitude ($\sim 10^6$) smaller for the production of the same amount of thermal energy (6):

$$n + d = t\ (6.98\ \text{keV}) + \gamma\ (6.25\ \text{MeV}) \qquad (5)$$

$$t + d = {}^4\text{He}\ (3.5\ \text{MeV}) + n\ (14.1\ \text{MeV}) \qquad (6)$$

$$n + d = n' + d' \qquad (7)$$

$$d + d = {}^3\text{He}\ (0.82\ \text{MeV}) + n\ (2.45\ \text{MeV}) \qquad (8)$$

$$= t\ (1.01\ \text{MeV}) + p\ (3.02\ \text{MeV}) \qquad (9)$$

$$= {}^4\text{He}\ (76.0\ \text{keV}) + \gamma\ (23.8\ \text{MeV}) \qquad (10)$$

Branching ratios of the last three reactions are known as 0.5 : 0.5 : 10^{-6} in nuclear physics.

3. Conclusion

The investigation given above again showed that the TNCF model explains qualitatively the experimental data on the excess heat generation in a Ni-H system as in the preceding cases of the anomalous excess heat (4,5) and neutron bursts (6) in Pd-D and Ti-D systems. According to our model, it is expected that the deuteron with energy 1.33 keV generated in reaction 1 will appear in some form in the experiment. One possible effect is an emission of deuterons from the sample with energy of 1.33 keV without any loss of energy by channeling in the material. A second possible effect is the formation of ^{3}He by reaction 2. Detection of ^{3}He is expected.

As is emphasized in the previous paper (5), the poor reproducibility of experimental results in cold fusion phenomena is attributed to the stochastic nature of conditions to realize neutron trapping. Though the reproducibility of the phenomena was largely improved in the Ni-H system (3), excess heat changed case by case.

The number of neutrons (10^{12} per second) to explain the experimental data seems too large to be consistent with experimental data obtained hitherto. One possible explanation is the existence of many cold neutrons in nature which are not detected with the usual technique of using dynamical reactions of charged particles from the neutron.

Thus, we can understand the complex phenomena occurring in cold fusion on the plausible assumption of neutron trapping in inhomogeneous materials without making unreasonable assumptions on the elementary processes. All reactions are familiar to modern scientists and unknown factors like neutron trapping mechanisms are beginning to show their shape (8,9). Conscious efforts to detect the working mechanisms in complex but interesting phenomena along the line of the TNCF model will reveal the physics of cold fusion.

References

1. M. Fleischmann and S. Pons. Electrochemically Induced Nuclear Fusion of Deuterium. *J. Electroanal. Chem.* 261, 301 (1989).
2. S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne, and S. E. Tayler. Observation of Cold Nuclear Fusion in Condensed Matter. *Nature* 338, 737 (1989).
3. F. Piontelli, S. Focardi and R. Habel. Anomalous Heat Production in Ni-H System. *Nuovo Cimento,* 107A, 163 (1994).
4. H. Kozima. How the Cold Fusion occurs? *Rep. Fac. Science, Shizuoka Univ.* 28, 31 (1994).
5. H. Kozima. Trapped Neutron Catalyzed Fusion of Deuterons and Protons in Inhomogeneous Solids. *Proceedings of ICCF 4 (1993)*, vol. 1, p. 5–1 Electric Power Research Institute, Palo Alto, California (1994); *Trans. Fusion Tech.* 26, 508 (1994).
6. H. Kozima and S. Watanabe. t-d and d-d Collision Probability in the Trapped Neutron Catalyzed Model of the Cold Fusion. *Proceedings of International Symposium "Cold Fusion and Advanced Energy Sources"* Minsk, May 24-26, 1994 (in Russian), p. 299.
7. H. Kozima. Neutron Moessbauer Effect and the Cold Fusion in Inhomogeneous Materials. *Nuovo Cimento* 27A, 1781 (1994).
8. G. F. Cerofolini and A. P. Para. Can Binuclear Atoms solve the Cold Fusion Puzzle? *Fusion Tech.* 23, 98 (1993).
9. G. F. Cerofolini, G. Boara, S. Agosteo and A. Para. Giant Neutron Trapping by a Molecular Species Produced during the Reaction of D$^+$ with H$^-$ in a Condensed Phase. *Fusion Tech. 23, 465 (1993).*