A UNIFIED INTERPRETATION OF COLD FUSION PHENOMENA IN THE TNCF MODEL

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Abstract

A unified interpretation of cold fusion phenomena is given based on the Trapped Neutron Catalyzed Model for Cold Fusion (TNCF Model), developed by the author for these past two years. Recent calculations of the neutron band and the lifetime of trapped neutrons are included.

1. Introduction

After the discovery of excess heat supposed to be due to cold fusion (CF), many and varied facts have been disclosed. Common key materials are, of course, hydrogen isotopes, i.e., hydrogen (H) and deuterium (D).

At first, only deuterium had been used for CF, while hydrogen was considered inactive and stable against fusion, even used even for reference systems to check CF events. The situation very much changed when it was recognized that hydrogen can also be responsible for CF phenomena.

Change has also occurred in the type of state of the hydrogen isotopes existing in CF materials. At first, only metal hydrides were used but now there are many compounds including proton conductors, oxide superconductors, and others which can absorb great amounts of hydrogen isotopes, and also compounds which contain hydrogen isotopes as one of their components, e.g., KD_2PO_4.

It is now recognized that an unstable or nonequilibrium state is indispensable to realize a CF phenomenon in any system. To realize unstable states, compound structures of samples with multi-components (Arata, Patterson, Yamaguchi, et al.), and voltage (Takahashi et al.), temperature (De Ninno et al.), and pressure (Yamaguchi et al.) variations, etc., have been used. It is remarkable that in ferroelectrics and superconductors the CF phenomenon occurs only in the transition temperature domain.

There is also a variety of CF products; in addition to the initially observed large excess heat, there are neutrons of various amounts and energies, tritium of various amounts, sometimes ^{4}He, gamma rays, protons, etc.

One of the most distinguished characteristics of these events in CF is low reproducibility. Though efforts of sincere researchers have improved its qualitative reproducibility, and therefore statistical reproducibility, the quantitative reproducibility expected for single-particle phenomena does not exist in a CF phenomenon, suggesting its statistical nature.

Here is the branching point between us who are affirmative for, and those negativists who are against CF science: it is therefore necessary to construct a theory with which we can explain low reproducibility, among other problems of generation of the various fusion products.

In any theory of CF, it is necessary to discover a missing factor (MF) as an indispensable member, which has not been recognized in physics until now, and is responsible for CF phenomena. The negativists deny the existence of a MF and therefore do not "believe" CF, in their words.

The affirmatives allow the existence

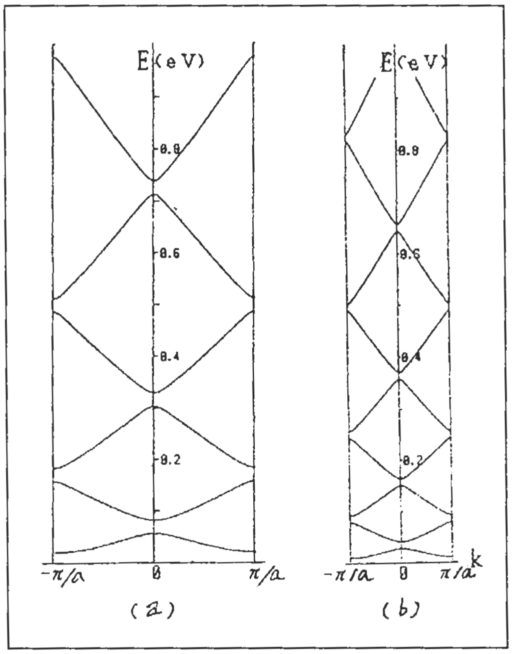

Figure 1. Energy bands of low energy neutrons in a one-dimensional solid with lattic constant a. Kronig-Penny attractive potential with zero width limit is used. The parameter is $P = 3\pi/2$, a = (a) 10^{-8}, (b) $\sqrt{2} \times 10^{-8}$ cm.

of a MF and try to discover it (or them) through ordinary scientific procedures. Naturally enough, however, they make various approaches for the final goal. Some would like to resolve the problem instantly by finding out a decisive MF that would cause a fundamental change in physics. Others would like a mild MF, not destroying present established physics. It should be noted that the present status of CF research justifies the phenomenological approach as it has sometimes worked very effectively to develop fundamental theory. (A typical example is the Bohr model for atomic structure.)

Anyway, among affirmatives it is common to recognize that the MF for CF has not been found until now, even though there are differences about whether it will change some of the existing principles, or will be deduced from them.

The present author has chosen the latter way in constructing the TNCF Model because he believes in the fundamental principles of present physics. The following is a trial interpretation of CF phenomena consistent with the TNCF Model in its most recent version. The MF in the model is only the trapped neutron, without any change in physical principles. The mechanism to trap neutrons in a crystal lattice rests in the undeveloped physics of neutrons—lattice nuclei systems interacting with the nuclear force in solid state/nuclear physics, which will be discussed in Section 3.

2. Trapped Neutron Catalyzed Model for Cold Fusion (TNCF Model)

If we assumed the trapping of stable neutrons in a crystal, we could explain CF phenomena from low reproducibility to various products in various materials (TNCF Model)[1–5].

1. Fundamentals of TNCF Model is summarized as follows:

A trapped neutron in a material containing hydrogen isotopes fuses with one of hydrogen isotopes. The reaction works for CF phenomenon as a trigger ("trigger reaction");

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

$$n + d = t\,(6.98\text{ keV}) + \gamma\,(6.25\text{ MeV}), \qquad (2)$$

The produced high energy particles d and t can fuse with hydrogen isotopes in the material successively according to reactions below:

$$p + d = {}^3\text{He}\,(5.35\text{ keV}) + \gamma\,(5.49\text{ MeV}), \qquad (3)$$

$$d + d = {}^3\text{He}\,(0.82\text{ MeV}) + n\,(2.45\text{ MeV}), \qquad (4)$$

$$= t\,(1.01\text{ MeV}) + p\,(3.02\text{ MeV}), \qquad (5)$$

$$= {}^4\text{He}\,(76.0\text{ keV}) + \gamma\,(23.8\text{ MeV}), \qquad (6)$$

$$t + d = {}^4\text{He}\,(3.5\text{ MeV}) + n\,(14.1\text{ MeV}), \qquad (7)$$

$$d + {}^3\text{He} = {}^4\text{He}\,(3.67\text{ MeV}) + p\,(14.7\text{MeV}). \qquad (8)$$

Those reactions are "breeding reactions" generating energy and reaction products, amount of them depend on the situation in the material they occur in it. The situation depends on stochastic processes in preparation of the sample.

Trigger reactions (1) and (2) work just to ignite following chain breeding reactions and the numbers of events of them might be small compared with those in the breeding reactions. This makes the number of photons expected to come out from the reactions (1) and (2) so small that it is difficult to observe them.

2. There are several facts on the role of background neutrons:

a) Null results without background neutrons[6,7].

There are many experimental results which show null results without background neutrons. Negativists against CF rest on these results, along with low reproducibility, to deny CF.

b) Effects of background neutrons[8–11].

There are several results showing that the background or artificial thermal neutron induces CF products.

3. The TNCF Model explains the low reproducibility of CF events as follows:

The condition to trap neutrons which induces trigger reactions (1) and (2) is dependent upon stochastic processes in the material[1]. The condition for the effective occurrence of chain breeding reactions (3) to (8) is also dependent upon stochastic processes in the material[2,3]. These stochastic processes are out of our control, even if we set adjustable parameters at definite values. This is the origin of the low reproducibility of CF events.

4. In relation with observation of 2.22 and 6.25 MeV photons expected to be generated in trigger reactions, it is remarked that there are only a few data in which they are observed[12–15]. These data were obtained in "dry experiments" (without water) except one "wet experiment" (with water)[12].

The detection efficiency of photons is minimal, in general, at about the 2 to 10 MeV energy domain. This fact might be relevant for the scarceness of the data concerning detection of 6.25 MeV photons. In addition to this fact, it is possible to assume that attenuation of the photon is very large in water for some reason.

3. Possibility of Neutron Trapping in Solids

The neutron trapping assumed in the TNCF Model has been investigated theoretically using knowledge of solid state-nuclear physics[16–19].

1) Neutron Mössbauer effect.

If a neutron is absorbed by or emitted from a nucleus in a solid, it is expected the event is recoilless (neutron Mössbauer effect). For a neutron below thermal energy, the ratio f of recoilless events to whole events are given by the following relation;

$$f = f_s^{R/R_s}, \quad (9)$$

$$f = \exp\{-3R_s/2k_B\Theta \cdot [1 + 2\pi^2/3 \cdot (T/\Theta)^2]\}. \quad (10)$$

In the above equations, R is the recoil energy of the nucleus when the event occurs in free nucleus, R_s is the recoil energy when a neutron with mass m_n and energy ε_s = 5.33 eV is emitted from ^{57}Fe nucleus in the free state (standard event); $R_s = m_n\varepsilon_s/M_s = 9.4 \times 10^{-2}$ eV. The ratio f_s is the value of f for the standard event at temperature T in a solid with Debye temperature Θ. (A neutron with energy 5.33 eV corresponds to a photon with 100 keV in momentum relation.)

For Pd in room temperature, the numerical relation between f and f_s is expressed as follows:

$$\ln f \cong 10^{-3} \ln f_s. \quad (11)$$

Because $f_s \cong 10^{-4}$, we obtain $f \sim 1$. This means almost all neutron emissions from and absorption by a nucleus in metal are recoilless.

When a neutron is absorbed effectively by a nucleus in a solid and is emitted effectively again, the neutron is played catch by nuclei in the solid, remaining there without the limitation of a free-state lifetime of 11 minutes.

If the absorption coefficient of a neutron by a nucleus is not large, a many-body effect works in the system composed of neutrons and lattice nuclei.

2) Neutron bands in solids[17]

In solids, a thermal neutron interacting with lattice nuclei (nuclei on lattice points) has an energy band structure. A band calculation has been given by the one-dimensional Kronig-Penny model[17]. The results are cited in figure 1 with the numerical data used given in the figure caption. Parameters are taken as follows:

$$P \equiv m_n abV_o/h^2 = 3\pi/2,\ a = 10^{-8} \text{ and } \sqrt{2} \times 10^{-8}.$$

The band structure shown in figure 1 predicts that a neutron in a crystal with large lattice constant a is reflected at a boundary to a crystal with small lattice constant a'. If a domain A with large lattice constant a is sandwiched by crystals with small lattice constant a', a low energy neutron in the domain A is trapped there. The wave function of the trapped neutron is a Bloch function, a standing wave with large amplitude at lattice nuclei (Bloch neutron).

This model calculation shows clearly a possibility of neutron trapping in the 3-dimensional crystal assumed in the TNCF Model.

3) Life time of a trapped neutron.

Neutrons trapped in a domain in a crystal interact with lattice nuclei through the nuclear force. This is a many-body problem. In this complex system, there could be various effects we have not encountered yet, comprising profound contents of solid state-nuclear physics.

For a zeroth-order approximation to treat this many-body problem, we have used a simplified interaction energy between Bloch neutrons and lattice nuclei: it is approximated by a lattice average of the interaction of a neutron and a nucleus in it. Also the interaction of Bloch protons and lattice nuclei is approximated by the lattice average of the interaction of a proton and a nucleus. Then, the difference of the two average interaction energy $< \Delta\varepsilon >$ gives a criterion of the stability of Bloch neutron in the lattice.

For several elements, the value of $< \Delta\varepsilon >$ are calculated using natural abundance for averaging[18,19]. The result is very interesting: for materials where CF phenomenon has been observed, $< \Delta\varepsilon >$ is always negative and the neutron trapped there is stable; metals Pd, Ti, Ni, and compounds $LaNi_5$, KD_2PO_4, $YBa_2Cu_3O_7$, etc.

This result might show that the zeroth-order approximation given above reflects something true related with a missing factor in solid state-nuclear physics.

A problem of whether a lattice nucleus absorbs a Bloch neutron or not will be determined by solving the many-body problem giving the energy difference between two states, stable Bloch waves and absorbed neutrons. It is interesting here to notice experimental data of a possible change of decay constant of tritium in solid[20].

4. Conclusion

The unified interpretation given above assumes the common mechanism for CF phenomenon observed in various materials. It is, of course, possible to assume that various mechanisms are responsible for various events observed in various materials.

Though various new discoveries in CF (Lipson 1994, Piantelli 1994, Patterson 1995 etc.) have been reported in a couple of years, it might be useful for the development of research to give an unified interpretation from one point of view. It is desirable that we have higher quality of experiments and more open discussions of experimental conditions and results. Open discussion of theories and experiments will make the science of CF fruitful.

The author hopes that this report gives something useful or instructive to attendants of the conference in their future works. CF

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INFORMAL SEMINAR ON "CURRENT COLD FUSION RESEARCH AT BARC"

16 June 1995, Bombay India

courtesy of Mahadeva Srinivasan

Preface

The BARC Cold Fusion Forum was founded in March 1995 to promote interaction and exchange of information regarding this fascinating and intriguing new field of multidisciplinary scientific endeavor which has come to be known as cold fusion. At present about 50 researchers, many of whom are engaged in cold fusion related studies, either full time or part time, are associated with the activities of the forum. The forum is open to all persons interested in getting to the bottom of the mystery.

The present seminar is being organized with a view to informing members of the current research activities in this area at BARC.

—R. Sundaresan, Convener of the Cold Fusion Forum

1. Protocol for controlled and rapid loading/unloading of H_2/D_2 gas from self-heated palladium wires to trigger nuclear events

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It has now been established that during electrolysis of LiOD using Pd cathodes, a threshold loading ratio of at least 0.85 needs to be achieved before excess heat production can be expected. However, for the production of neutrons and tritium (and possibly charged particles and transmutation