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Neutron Mössbauer Effect and the Cold Fusion in Inhomogeneous Materials.

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Summary. — In relation with the trapped-neutron catalized model (TNCF model) to explain the Cold Fusion phenomenon, the neutron Mössbauer effect is proposed to trap neutrons in a crystal composed of nuclei which can absorb a neutron resonantly to form an excited state of an isotope. This mechanism of neutron trapping depends on the distribution of the protons (and / or deuterons) in the lattice and is responsible for the poor reproducibility, one of the characteristics of the Cold Fusion phenomenon.

PACS 25.70.Jj - Fusion reaction, cold fusion.
PACS 76.80 - Mössbauer effect; other γ-ray spectroscopy.

1. - Introduction.

The Cold Fusion phenomenon in metal hydrides [1-4] is attracting strong interest of various people in the society. Because of the complex nature of the phenomenon there are keen conflicts in terms of the estimation of experimental results.

To resolve the confusion in the interpretation of the experimental results, a model was proposed [5-8] which could explain qualitatively (or semi-quantitatively in several points) some characteristics of the phenomenon in which were included the large excess heat generation in Pd-D not found in Ti-D system, the neutron bursts in these metal halides, and tritium anomaly, *i.e.* large tritium-to-neutron ratio.

The model assumes an effective trapping of neutrons in an inhomogeneous material occluding proton or deuteron. Though the mechanism proposed to trap the neutron includes the total and Bragg reflections of neutrons by boundaries between regions with different solute density, a many-body effect similar to that resulting in Anderson localization and the temporal absorption of the neutron by a matrix nucleus are suggested. One more important mechanism, the recoilless emission and absorption of neutrons by matrix nucleus (the neutron Mössbauer effect, *i.e.* NM effect) should be added as a mechanism responsible for the neutron trapping as will be explained in the following section.

2. – Neutron Mössbauer effect.

Let us consider a metal hydride composed of a lattice of matrix nucleus and occluded protons (and/or deuterons) which distribute in the lattice inhomogeneously as a solute (we will consider only the proton case hereafter for simplicity).

A neutron with an energy ε can be absorbed by a nucleus in a lattice if the nucleus has a resonance absorption level at ε according to the Mössbauer mechanism (M-mechanism) similar to the recoilless absorption and emission of a photon in the crystal. A neutron with an energy 5.33 eV has the same momentum as that of a photon with energy 100 keV which corresponds to the photon usually used in the Mössbauer resonance technique. Thus, the ordinary crystal can give rise to the neutron Mössbauer effect for neutrons with energy less than the thermal one.

The neutron absorbed by a nucleus $N(A)$ with a mass number A forms an excited state $N^*(A+1)$ of the nucleus with a mass number $A+1$ by the NM effect. The nucleus $N^*(A+1)$ will then emit a neutron with energy ε with a delay time τ again by the M-mechanism. The emitted neutron could be absorbed again by another nucleus $N(A)$ with the same mechanism. This process may repeat many times in a crystal in an optimum situation if there is a neutron with energy ε and an array of matrix nucleus $N(A)$ with a resonance level at ε for a neutron.

The nucleus with the even atomic number Z around 26 includes many isotopes with different mass number A and with a small change of mass defect between them. For those nuclei, the difference of the nuclear mass

$$\Delta M = M(A) + 1.009214 - M(A+1)$$

of a pair of isotopes with the mass number difference $\Delta A = 1$ plus the mass of a neutron has a small value compared with the mass defect of the nucleus and the small A isotope will be able to absorb the low-energy neutron resonantly to form an excited state of the large A isotope and will emit it again in a short time. The nuclei known to induce the Cold Fusion, Ti, Ni and Pd, belong to this group. In those nuclei, the most or second abundant nucleus has isotopes with $\Delta A = 1$ and ΔM of the order of 10^{-2} a.m.u. $\sim 10^4$ keV. This fact means that the nucleus has many resonance levels at energies for a small energy and responsible for the NM effect.

To accomplish the Cold Fusion, the material should include a lot of protons (and/or deuterons). The inclusion of protons in a crystal occurs as a result of diffusion (a stochastic process) and the resulting distribution of the proton in the lattice has inevitably local inhomogeneity. This local inhomogeneity will impair the recoilless emission and absorption by M-mechanism.

The M-mechanism depends on the dynamic character of the local lattice around the pertaining nucleus. In an inhomogeneous material where the Cold Fusion occurred, it was known that the dynamical characteristics of the lattice varied from place to place. However, according to the M-mechanism, the size of the locally homogeneous region (pure matrix region) (LH region) should have a minimum value to keep the lattice effective to induce the NM effect. On the other hand, to have a long trapping time T of the neutron in the material by the NM effect, it is necessary to have as many nuclei in the homogeneous lattice as possible, *i.e.* to make the total volume of LH region as large as possible.

The neutron in a free state decays by the beta disintegration with a time constant of 10^3 second. While in the stable nucleus, the neutron is stable interacting with other nucleons. If the neutron in a crystal experiences a successive emission and absorption by the matrix nuclei, the crystal works effectively as a neutron reservoir. This situation might be relevant with a very large neutron density estimated from excess heat generation data by the trapped neutron catalyzed fusion model [8].

In view of the neutron Mössbauer effect (NM effect) with respect to the Cold Fusion, the occlusion of hydrogen contradicts the effectiveness of the NM effect. To reconcile the two conditions, it is necessary to have a periodic structure of proton occluded and not occluded regions in the sample. The protocols for loading the hydrogen into nickel used in the experiment [4] might be effective to realize the condition in the sample.

The observation of the neutron trapping by molecular species [9, 10] might be relevant with the NM effect proposed in this paper, though the authors assumed a mechanism of resonance trapping by a binuclear atom.

3. – Conclusion.

The idea of the nuclear Mössbauer effect seems attractive in respect of the Cold Fusion to keep the low-energy neutrons in the sample fusing with the occluded proton (deuteron). Controlling the amount and the energy of the low-energy neutrons in the sample, we will be able to check the effect of the neutron on the Cold Fusion phenomenon.

The reality of the NM effect will be checked directly by a techniques similar to the ordinary (photon) Mössbauer effect with thermal neutron beam instead of the gamma-ray. If the effect is confirmed to work in the crystal, the solid-state nuclear physics with the low-energy neutron as a linking particle will be an abundant field of large scientific and technical interest.

From our view point on the TNCF model, the possible element to use for the Cold Fusion has to meet at least for two conditions: 1) the element can form a metal or a compound which occludes a lot of hydrogen (and therefore deuterium); 2) the element is composed of isotopes in which abundant isotopes have an isotope with $\Delta A = 1$ and $\Delta M \sim 10^3$ keV. One new candidate we know to meet the second condition from the table of isotopes is ^{28}Si with abundance 92.2% and the mass difference ΔM with ^{29}Si is $0.965 \cdot 10^{-2}$ a.m.u. Thus prediction will be easily checked using Si in H occluding or proton conducting materials.

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