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Research Article

The Conjecture of the Neutrino Emission from the Metal Hydrides

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Abstract

Selective Resonant tunneling model has been successful to explain the three major puzzles in cold fusion proposed by nuclear physicist (i.e. penetration of Coulomb barrier, no neutron emission, no gamma radiation), and successful also to explain the three major cross-section data in hot fusion(i.e. d+t, d+d, d+He^3). Its prediction about 3-deuteron fusion has been found in experiments as well. The reasonable inference is the neutrino emission from the metal hydrides. The feasibility of detection of this neutrino is discussed in this note.

Keywords: Condensed matter nuclear science, 3-Deuteron fusion reaction, KamLAND, Metal hydrides, Neutrino emission, Selective resonant tunneling

1. Theory—Resonance Selects Damping

Selective resonant tunneling theory predicts that there should be a state of long life-time with two deuterons inside the metal crystal lattice when deuterium gas is absorbed by a metal. This has been verified in Japan, and we further guess that this long life-time state would emit neutrino which is detectable within the sensitivity of KamLAND neutrino detector.

It is well known that hydrogen molecule will be dissociated into hydrogen atoms when hydrogen is absorbed by metal. The hydrogen atoms will be further ionized into protons and electrons in the crystal of metal. In general, those protons are trapped and separated by the lattice potential. The distance between them is similar to or even greater than the distance in a hydrogen molecule. The opportunity for them to approach each other is exponentially small due to the Coulomb barrier between two positively charged protons. The same is true for a pair of deuterons inside the metal crystal lattice. The probability for a pair of deuterons to approach each other is exponentially small as well. However, once a pair of deuterons stays together, it will form an excited state of the helium nucleus. This excited state of the helium nucleus will decay through strong nuclear interaction or electromagnetic interaction. However, according to the selective resonant tunneling theory [1,2], another kind of excited state of the helium nucleus will be generated. It is a product of the resonant tunneling through a thick and high Coulomb barrier inside the metal crystal lattice. The

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resonant tunneling will select only the state with long life-time because the resonant tunneling would not be valid if the life-time of that state is not long enough. Hence, this state must decay through some weak interaction instead of any strong nuclear interaction or electromagnetic interaction. The most important test of this selective resonant tunneling theory is to search for this long life-time resonant state of two deuterons.

2. Experiment—Evidences for Long Life-time State

Three deuterons might interact if two deuterons stay together with a long life-time in a target while the third deuteron is impinging on this target. The longer this life-time is, the greater the opportunity to see this 3-deuteron reaction. Professor Kasagi of Tohoku University observed this 3-D fusion reaction early in 1993 in Nuclear Science Laboratory [3].

About 150 keV deuteron beam bombarded on a titanium target, which had absorbed a lot of deuterium gas in advance to form TiD_x with $x > 1.2$. Usually, we expect only the 2-body fusion reactions, because the probability of 3-body fusion reactions is almost zero. However, Kasagi observed the 3-body fusion reactions with much more probability. Every 10^5 2-body fusion reactions he observed one 3-body fusion reaction. In comparison, the theoretically expected value was only one 3-body fusion reaction in every 10^{31} 2-body fusion reactions.

In 1995–1997, Professor Takahashi of Osaka University confirmed this discovery in terms of another reaction channel [4]. Kasagi studied the reaction channel: $\mathrm{d} + \mathrm{d} + \mathrm{d} \to \mathrm{p} + \mathrm{n} + {}^4\mathrm{He}$ ($Q = 21.62$ MeV), and Takahashi studied the reaction channel: $\mathrm{d} + \mathrm{d} + \mathrm{d} \to \mathrm{t} + {}^3\mathrm{He}$ ($Q = 9.5$ MeV). Kasagi found that the maximum energy of the proton and ^{4}He were 17 and 6.5 MeV, respectively. These could not be explained if only 2-body fusion reactions were involved. 3-body fusion reaction of $\mathrm{d} + \mathrm{d} + \mathrm{d} \to \mathrm{p} + \mathrm{n} + {}^4\mathrm{He}$ ($Q = 21.62$ MeV) explained not only the maximum energy of the proton and ^{4}He, but also the shape of the continuous energy spectrum of the protons and ^{4}He. Takahashi confirmed 3-body fusion reaction: $\mathrm{d} + \mathrm{d} + \mathrm{d} \to \mathrm{t} + {}^3\mathrm{He}$ in terms of the energy of triton and ^{3}He (4.75 MeV), and their equal yields. Both Kasagi and Takahashi obtained the similar ratio of the 3-body reaction rate to 2-body reaction rate:$\sim 10^{-5}$. Takahashi further estimated the life-time of the state of two deuterons based on this ratio of reaction rates. The life-time of the 2-deuteron resonance state was estimated to be $10^4 - 10^5$ s, which was just in the range predicted by the selective resonant tunneling model.

3. Neutrino Emission—Feasibility of Detection

Such a long life-time state can only decay through some weak interaction, because the strong nuclear interaction or electromagnetic interaction is too strong to have such a long life-time. The weak interaction is supposed to be accompanied by neutrino emission although we do not know exactly which kind of weak interactions are involved. Is it feasible to detect such a weak neutrino emission using KamLAND neutrino detector?

The recent visit to Research Center for Neutrino Science at Tohoku University gave us the impetus to consider this feasibility with four favorable factors:

(1) *Sensitivity*. KamLAND detector requires that on its spherical surface the neutrino flux should be of the order of $10^6/\mathrm{s/cm}^2$. The diameter of this spherical surface is of 13 m. Hence, it requires that at the center of this spherical scintillation liquid there is a neutrino source which has the intensity of 6×10^{12}/s. It corresponds to an "excess heat" power of Watts. Nevertheless, it is possible to have such amount of "excess heat" power in the metal hydride frequently [5,6] if the "excess heat" is from the recoil energy due to the neutrino emission.

(2) *Energy*. KamLAND detector has successfully detected the solar neutrino, the fission reactor neutrino, and the geo-neutrino; hence, it is easier for KamLAND detector to obtain the better ratio of signal to noise if the energy of the unknown neutrino source is greater then 5 MeV. Indeed the preliminary estimate of the energy from the metal hydride is just above 5 MeV (see Section 4).

(3) *Purification of scintillation liquid*. KamLAND detector is composed of a high-purity scintillation liquid. Its impurity is at the level of 10^{-5}. It is scheduled to further purify the scintillation liquid this year. Its impurity level would be further reduced to 10^{-7}. Hence, the ratio of signal to noise would be further enhanced accordingly.

(4) *Volume*. The volume at the center of the KamLAND detector is quite ample for the metal hydride. It is feasible to enhance the "excess heat" power level by a factor of 10–100 just based on the volumetric effect.

4. Weak Interactions

Three kinds of weak interactions are in consideration: K-electron capture, electron-catalyzed fusion reaction, and Mitsubishi–Iwamura type of nuclear transmutation.

(1) *K-electron capture*. K-shell electron of deuterium atom might be captured by the deuteron with very little probability. There are two factors which might change this situation. (i) The selective resonant tunneling is favorable to the low probability process; (ii) The K-electron would have much more chance to interact with the deuteron of which the wave function is a linear combination of two states: the helium-like excited state and the deuterium molecule-like crystal trapped state.

(2) *Electron-catalyzed fusion*. The electron might be captured by a tunneling deuteron, and form a virtual di-neutron in the nuclear well to produce a ^{4}H* state which would be followed by a decay process to make a ^{4}He* from this ^{4}H* state: i.e.

$$\mathrm{d} + \mathrm{d} + \mathrm{e} \rightarrow {}^4\mathrm{H}^* + \nu_\mathrm{e},$$

$${}^4\mathrm{H}^* \rightarrow {}^4\mathrm{He}^* + \tilde{\nu}_\mathrm{e} + \mathrm{e}.$$

The net effect is

$$\mathrm{d} + \mathrm{d} \rightarrow {}^4\mathrm{He}^* + \tilde{\nu}_\mathrm{e} + \nu_\mathrm{e} + \text{Lattice } (Q = 23.8 \text{ MeV}).$$

It seems like an electron-catalyzed fusion reaction to emit a pair of neutrino and anti-neutrino. This anti-neutrino emission is favorable to KamLAND detector as well. The maximum energy of this anti-neutron is about 23 MeV, and the maximum recoil energy of ^{4}He is about 23 MeV also when lattice is involved in momentum conservation. These numbers may be compared with the experimental observation.

(3) *Mitsubishi–Iwamura nuclear transmutation*. Cesium ($^{133}_{55}$Cs) thin film on the surface of a Pd–CaO–Pd super-lattice complex might be transmuted into praseodymium ($^{141}_{59}$Pr) while a deuterium flux is permeating through this complex [7]. Four deuterons might be added into this cesium nucleus in terms of the electron-catalyzed process which might be accompanied by emission of a pair of neutrino and anti-neutrino. Although it is not quite clear about the transmutation processes, but the neutrino emission must be there if it is a weak interaction process in nature.

5. Discussion

(1) Is electron capture by deuteron in lattice a real process?
K-capture of electron in nucleus might be accompanied by a positron emission process if the mass excesses allow this positron emission. However, during K-capture of electron in deuteron, ($\mathrm{d}+\mathrm{d}+\mathrm{e} \rightarrow {}^4\mathrm{H}^*+\nu_\mathrm{e}+0.372$ MeV,) the mass excesses do not allow the positron emission ($\mathrm{d} + \mathrm{d} \rightarrow {}^4\mathrm{H}^* + \nu_\mathrm{e} + \mathrm{e}^+$) if ^{4}H* is a real one (i.e. the

mass excess of $^4H^*$ takes 25.9 MeV). This consists with one aspect of the experimental fact (the products of positron annihilation, two 0.511 MeV photons, were not observed). Hence, one may expect that electron capture by deuteron in lattice might be a real process instead of a virtual process. Nevertheless, if $d + d + e \rightarrow {}^4H^* + \nu_e + 0.372$ MeV was a real process we were supposed to see the neutrino with single energy, and the neutron as the decay product of the $^4H^*$. These are not confirmed by experiments either. Indeed positron emission was not observed just due to the selectivity of resonant tunneling. Because the 3-body products in the channel of positron emission has a greater phase space available, its probability of transition is usually greater than that of the 2-body product channel (i.e. electron capture channel). As a result, the life-time for positron emission is much shorter than that of electron capture. The selectivity of resonant tunneling just picks the longer life-time for such a thick and high Coulomb barrier at low energy (see calculation in the Proceedings of ICCF-9 [8]). Thus, we assume that electron capture by deuteron in lattice is a virtual process.

(2) Is "excess heat" the recoil energy?
If the electron capture is a virtual process, and the electron just plays the role of a catalyst; then, the energy would be distributed among ^4He, neutrino and anti-neutrino with a little energy to lattice. The energy of ^4He would be in the range from 75.8 keV to 23.8 MeV. Then we are supposed to see much more ^4He than those observed in the "excess heat" experiments. A possible explanation is that most of the ^4He were trapped by lattice. ^4He would move out from lattice only if the temperature of palladium was higher than 1000^{o}C which is much higher than that in any electrolysis experiment or most of the gas-loading experiment.

(3) Analogy to inner conversion
When excited nucleus de-excites, the released energy may became the energy of photon, or the energy of orbital electron. At the first glance,it was easy to think of that the nuclear energy was transfer first to a real photon first; then the photo-electric effect kicked out the orbital electron. Later it was found that the nuclear energy might be transferred to orbital electron through a virtual photon without any photo-electric effect in between. Now we may imagine that the nuclear energy was transferred to neutrino and anti-neutrino through a virtue electron capture process in those weak interactions in a lattice.

6. Proposal of Experiment

All the three above-mentioned reactions emit neutrino with energy higher than 5 MeV. Hence, we may propose that putting the metal hydride in the control room of KamLAND neutrino detector near the big liquid sphere of scintillator to run the first step of experiment in order to confirm the emission of the neutrino, and measure the energy of those neutrinos.

After the confirmation of the neutrino emission, we may reconstruct the set-up of the metal hydride in order to put this metal hydride into the center of the spherical liquid scintillator, and determine the spectrum of this neutrino emission.

Early in 1989, the first generation of neutrino detector at Kamiokande was used to detect the neutron emission from the Pd–D_2O electrolytic cell. Its result of no neutron emission is still valid today, and becomes the foundation of the theory of the selective resonant tunneling in condensed matter nuclear science. We may expect that the third generation of the neutrino detector (KamLAND) might contribute to this greatest scientific exploration as well.

As long as the neutrino emission is confirmed, we may solve a long-lasting controversial puzzle in the scientific world, and a nuclear energy without strong nuclear contamination is thus feasible.

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References

[1] Xing Z. Li, Jian Tian, Ming Y. Mei, Chong X. Li, Sub-barrier fusion and selective resonant tunneling, *Phys. Rev.* **C 61** (2000) 024610 .

[2] Xing Z. Li, Bin Liu, Si Chen, Qing Ming Wei, and Heinrich Hora, Fusion cross-sections for inertial fusion energy, *Laser Part. Beam* **22** (2004) 469 .

[3] J. Kasagi et al., Energetic protons and alpha particles emitted in 150-keV deuteron bombardment on deuterated Ti, *J. Phys. Soc. Japan* **64**(3) (1995) 778 .

[4] A. Takahashi et al., Anomalous enhancement of three-body deuteron fusion in titanium-deuteride with low-energy D^+ beam implantation,*Fusion Technol.* **34** (1998) 256 .

[5] G. Fralick et al., Results of an attempt to measure increased rates of the reaction $D + D \longrightarrow {}^3He + n$ in a Nonelectrochemical Cold Fusion Experiment, *NASA Tech. Memo.* (1989) 102430.

[6] Xing Z. Li et al., Correlation between abnormal deuterium flux and heat flow in a D/Pd system, *J. Phys. D: Appl. Phys.* **36** (2003) 3095–3097.

[7] Y. Iwamura et al., Elemental Analysis of Pd Complexes: Effects of D_2 gas permeation, *Jpn. J. Appl. Phys.* **41** (2002) 4642.

[8] Si Chen, X.Z. Li, Tritium production and selective resonant tunneling model, in: X.Z. Li (Ed.), *Proceedings of ICCF-9* (Tsinghua University Press, Beijing China, May 19–24, 2003) 2002, 42.