Explaining the Cold Fusion Phenomenon Using the TNCF Model

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The cold fusion phenomenon occurring in solids with hydrogen isotopes has been explained using the TNCF model[1~10] with a single adjustable parameter n_n, the value of which was between $10^6 \sim 10^{13}$ cm^{-3}. The parameter n_n is proposed as a density of trapped thermal neutrons in the solids. This explains the reported phenomenon from excess heat generation to nuclear transmutation (NT), with a large shift of the atomic and mass numbers in addition to the nuclear products (tritium, ^{4}He, neutron, gamma, etc.) generation and NT with a small shift of the atomic and mass numbers.

In the analyses such proposed riddles as the tritium anomaly (imbalance of the generated tritium and neutrons), the excess heat anomaly (imbalance of the excess heat and neutrons), and helium production (unexplainable amount of helium compared with neutron) are qualitatively (and quantitatively in several cases) solved using the assumed premises.

The success of the model suggests that there may be reflection of truth in the model. Investigation of premises in the model so successful in interpretation of various events is the theme of this paper to figure out some phases of the truth of the cold fusion phenomenon.

1. Value n_n Between $10^6 \sim 10^{13}$ cm^{-3}.

As shown in the Tables in the previous papers[9,10], the values of n_n determined by experimental data of the excess heat, tritium, helium and/or nuclear transmutation are consistent in each experiment with several events at its high time (when the events are observed) and are in the range of $10^6 \sim 10^{13}$ cm^{-3}. This is a remarkable result considering the variety of the events including the excess heat generation, tritium, helium, neutron productions and nuclear transmutation (NT).

Not asking the origin of the trapped neutrons with these densities, the value itself is not so large compared with the Loschmidt's number $N_L = 2.69 \times 10^{19}$ cm^{-3}, the density of an ideal gas in the standard state. The density of atoms in a solid is usually about a thousand times higher than this value and the above values of n_n are at most 10^{-9} of the density of atoms in solids.

As is well known, there are a plenty of ambient neutrons on the earth which are an obstacle in a precision measurement of radiations including neutrons. As several precise measurements of neutrons originating in the cold fusion phenomenon have shown, the cold fusion events are not observed without background neutrons. All experiments with a positive result has been done in circumstances with finite background neutrons. These experiences, in addition to success of the TNCF model with n_n in the range of the above values, strongly suggest the importance of neutrons in the cold fusion phenomenon.

There remains a question about the possible explanation of existence of such a trapped neutron in solids using conventional Quantum Mechanics. This question leads us to a new idea of the neutron affinity of a nucleus in addition to the not widely noticed concept of neutron bands in solids.

2. Neutron Bands In Solids

The thermal neutron with energy 0.025 eV corresponding to a temperature of 300 K has a de Broglie wave length 1.80Å, comparable to lattice constants of crystals of about 3 ~ 4 Å. This is the reason the neutron diffraction is widely applied in technology and science using neutrons from atomic piles. A neutron with thermal energy propagates through a crystal as a Bloch wave, just like electron Bloch waves widely applied in solid state electronics. This situation also shows a possibility of neutron trapping in a crystal surrounded by another crystal with a different energy band structure due to the difference of lattice constants.

A simple example of such a situation to trap neutrons by the neutron band mechanism had been shown in a previous paper[11] by a numerical calculation. Therefore, a neutron can be trapped in a crystal surrounded by another crystal with an appropriate lattice constant, in principle.

3. Neutron Affinity of a Nucleus

The next problem about the trapped neutron is its stability against the beta decay. Its constant in vacuum is 887.4 s with an energy liberation of 782 keV. Let us assume that the neutron Bloch wave trapped in a crystal transforms into a proton Bloch wave when it performs β decay. Furthermore, let us estimate the stability of the neutron wave interacting with a nucleus with a neutron affinity η defined by the following relation;

$$\eta \equiv -\left({}^{A+1}_{Z}M - {}^{A+1}_{Z+1}M \right) c^2 \text{......(1)}$$

Here, c is the light speed in vacuum, ${}^{A}_{Z}M$ is the nuclear mass of the nucleus with a mass number A and an atomic number Z composing the lattice nuclei.

This definition tells us that the neutron affinity is a quantity expressing an energy difference of two nuclear states, one with an extra neutron and the other with an extra proton. The positive value of η means the former is in lower energy than the latter and is more stable. For a crystal, we define the neutron affinity of the crystal $< \eta >$ as an average of η over the lattice nuclei. Therefore, the neutron affinity of a crystal composed of an identical nucleus is the same to that for the nucleus.

Furthermore, we may assume that when a neutron is trapped in a crystal with a positive neutron affinity $< \eta >$, then the neutron is stable against beta decay. Then, the Table of neutron affinity of elements[10~12] shows coincidence of occurence of the cold fusion phenomenon and the positive value of the matrix solids. Verification of the concept of "neutron affinity" is only given by such an indirect evidence as this now, the stability of a neutron in a nucleus interacting with protons in it suggests strongly existence of a similar effect when there is an interaction of a neutron Bloch wave with lattice nuclei.

4. Quasi-Stability of the Trapped Neutron

The trapped thermal neutron stabilized by the interaction with lattice nuclei can interact with a nucleus having large disturbance of the neutrons. Experimentally, this property is needed by the occurrence of the cold fusion events generating the excess heat, tritium, helium, nuclear transmutation, and so on. The irregularity of crystal potential on the neutron Bloch wave is large at the crystal boundaries and impurity nuclei in the crystal.

Experimental data show that many events occur in the surface region with a thickness of about few ~ 10 μm in, especially, electrolytic experiments. In experiments without electrolysis, surface layers seem not decisive but the volume has an effect in the cold fusion phenomenon.

In our analyses, we assumed effective interaction in volume is 1% of that in the surface layer, which is assumed the same as in a vacuum, giving a consistent explanation for all the data previously obtained in electrolytic and gas contact experiments. The success of the analyses seems support our idea of quasi-stability of the trapped neutrons in volume and in the surface layer.

The reactions induced by the trapped neutrons between nuclei in the system work as triggers for the whole cold fusion phenomenon. The energetic products of the trigger reactions between the trapped neutron and lattice nuclei (including those in the surface layer) induce succeeding breeding reactions which feed neutrons for the trigger reaction and also give results observed as events outside.

5. De-Stabilization of Nucleus Interacting with the Trapped Neutrons

The progress of the experimental work revealed vast nuclear transmutations in surface layers with large shifts of atomic and mass numbers in electrolytic and gas discharge experiments. From an energy point of view, relevant energies in these experiments are at most 1 eV compared with conventionally supposed necessary energy of 1 MeV for the nuclear reactions.

An idea is suggested by the quasi-stabilization of the trapped thermal neutrons. If a neutron Bloch wave is stabilized by the interaction with the lattice nuclei with a positive neutron affinity, a nucleus with a negative neutron affinity will be destabilized by an interaction with the trapped neutrons.

Almost all radioactive nuclei have a negative neutron affinity, with rare exceptions, and therefore accelerated its decay by an interaction with the neutrons in a surface layer deposited on the material including the trapped neutrons. Some nuclei in the surface layer on such a material will suffer a decay or a fission reaction by an interaction with the neutrons. These events analyzed by the TNCF model have given the value of n_n in the range mentioned above and consistent with other events as the excess energy generation.

6. Attenuation of Gamma Rays In Materials

There had been few observations of gamma rays from the cold fusion system and the rareness of the observation has forced people to seek some reactions with phonons instead of photons. In these several years, however, there are some data which show gamma rays with energies up to 10 MeV, possibly explaining the cold fusion phenomenon using conventional physics and without relying on a new principle or a new mechanism.

In the TNCF model, the fundamental reactions in an electrolytic system is independent of gamma emission and consistent with the lack of the gamma data. In the discharge and gas contact systems with deuterium, a fundamental reaction in the TNCF model is relevant with a gamma ray with an energy of 6.25 MeV. Though gamma rays have been observed in recent experiments, the frequency of the detection suggests a large attenuation of gamma rays in materials with a large concentration of deuterium. Our suggestion is the dissociation reaction of a deuteron by a photon with a fairly large cross section of about 2 mb in vacuum for $E_\gamma \sim 6$ MeV;

$$\gamma + d = p + n - 2.22 \text{ Mev.}$$

If this reaction works well in materials, the lack of gamma rays in the observation and the breeding of neutrons in the material are both explained simultaneously.

7. The Problem of Reproducibility

Reproducibility is the largest stumbling block of the cold fusion phenomenon for the skeptics. It is necessary to any theory to solve the irreproducibility of the phenomenon by some elements in it. The TNCF model gives an answer to this problem by the microscopic stochastic nature of understanding the conditions for trapped neutrons in materials with hydrogen isotopes. There is another stochastic factor of feasibility of trigger and breeding reactions conditioned by the density and distribution of hydrogen isotopes in the material even if there are trapped neutrons. These factors, having a stochastic nature, determine reproducibility (or rather irreproducibility) of the events of the cold fusion phenomenon in the same materials which seem identical from a macroscopic point of view.

We can, therefore, expect only a qualitative (or statistical) reproducibility for the cold fusion phenomenon, but not a quantitative reproducibility.

8. Conclusion

The cold fusion phenomenon, discovered nine years ago, caused a sensation at first and then decisive disbelief about its reality. There were many problems independent of science in the process of the change of its popularity. Piling up experimental data, we now have confidence in its reality, but so far we have no consistent explanation based on the microscopic principles. The model explanation given above will be a mile stone to establish a complete theory of the cold fusion phenomenon, the solid state - nuclear physics, the central part of which may be the physics of thermal neutrons in solids with hydrogen isotopes[12]. We can't yet give even a fragment of its possible vast perspective.

The application of the cold fusion phenomenon is also very interesting because its variety of events from the excess heat to the nuclear transmutation with small and large shifts of atomic and mass numbers. Most important of them will be as a new energy source without a limit of resources. And the second will be extinction of hazardous radioactive isotopes from atomic piles. The cooperation of science and technology will, we hope, make a sound progress.

Here we can give some predictions on the improvement of the cold fusion experiment based on the analyses by the TNCF model.

First of all, it is necessary to have an appropriate number of thermal neutrons in the experimental system to make the parameter $n_n 10^6 \sim 10^{13}$ cm^{-3}. This value is obtained at the high time of the events, though the initial value may be lower by several orders of magnitude.

Second, to maintain the cold fusion phenomenon, it is necessary to have deuterium or alkaline metal atoms (e.g. ^{6}Li) in inhomogeneous regions to trigger reactions responsible to the phenomenon. Surfaces of the sample seem to work as an effective inhomogeneous region and surface-to-volume ratio may be an index of the reproducibility.

Third, after a trigger reaction has occurred in the inhomogeneous region, the breeding reaction seems to occur in volume too. This suggests that volume-to-surface ratio (or total volume) may be an index of the strength of a burst of any kind (the excess heat, tritium, helium, neutron and so on).

Fourth, even in electrolytic systems where we don't expect to generate gamma rays in the trigger reaction, the breeding reaction may possibly generate gamma rays. It is better to be careful about the possible radiation hazard from cold fusion systems. We have to be careful about hazardous radiations even if it will be weak compared with those from atomic piles and plasma fusion machines.

Fifth, in preparing a device for an application, it is necessary to use a design where it is easy to replace any parts which might be damaged by nuclear reactions in the system.

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