“ABNORMAL” NUCLEAR PHENOMENA AND POSSIBLE NUCLEAR PROCESS

NUCLEAR REACTIONS IN SOLIDS

KEYWORDS: *abnormal phenomena, traditional idea, new process*

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A careful study of “abnormal” nuclear phenomena in a cold fusion experiment indicates that cold fusion is a new problem in ultralow energy, and we cannot use the traditional idea of deuteron-deuteron fusion to understand and appraise cold fusion. The contradiction between the new phenomena and traditional theory is analyzed, and a possible new nuclear process is suggested.

INTRODUCTION

The new phenomena observed in solid materials containing deuteron have stirred the interest of physicists and caused disputes among them. But the disputes are based on traditional nuclear fusion theory. Some researchers have also attempted to prove that cold fusion is deuteron-deuteron (*d-d*) fusion in the traditional sense, but so far, no one has offered any proof. Nuclear phenomena are called “abnormal” when the new phenomena cannot be explained by traditional nuclear fusion theory. In fact, after further study, we find that the abnormal nuclear phenomena do not belong within the framework of traditional theory. We cannot use traditional ideas to understand and appraise them. A new theory must be established.

The study of accelerator and nuclear physics has proceeded from low to medium energy and then to high energy since Rutherford proposed research on the nuclear reaction in 1919, but studies below 1-MeV energy have hardly been taken into account. So far, research on weak interactions at ultralow energy[a] is nonexistent.

Fermi observed a “semi-cold fusion” reaction between heavy ice and deuterium in 1937; Bascoli formed a “cold fusion” hypothesis based on emerging neutron and gamma particles in a fusion experiment with deuterons and lithium in 1984. Fleischmann and Pons declared “nuclear fusion at room temperature” in 1989. These phenomena are new problems in the ultralow-energy range. There is a part weak interaction force in nuclear force (see, for example, Ref. 1). If a deuteron can be excited by gathering energy for the capture process,[2,3] the excited deuteron can capture an electron in the lattice-atom to form a dineutron (${}^2_0N$) (Refs. 2 and 3) to conduct fusion of the deuteron-dineutron or the fusion of a dineutron and the other nucleus. Using the dineutron model can explain a series of “abnormal” nuclear phenomena,[2] and the dineutron has been measured in experiments.[4]

EXPERIMENTAL PHENOMENA AND TRADITIONAL THEORY

Reappearing Problem for Cold Fusion Phenomena

In an electrolytic cell experiment, an emissive neutron requires a long time to electrolyze heavy water; the palladium cathode absorbs deuterium; and neutron emissions are random bursts.

The length of time from the start of electrolysis to the production of neutrons is different for each experiments, and it is very difficult to determine beforehand. Under identical external conditions, the experimental phenomena sometimes reappear and sometimes do not,

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[a] Physicists usually divide the energy domain as follows:

1. low energy: from 1 to <100 MeV—a typical case is Rutherford’s nuclear reaction, finding protons
2. medium energy: from 100 MeV to 1 GeV—a typical case is meson production
3. high energy: from 1 to <1000 GeV—a typical case is finding J/Ψ particles
4. ultrahigh energy: >1000 GeV—a typical case is the Superconducting Supercollider, 2 × 20 000 GeV
5. ultralow energy: <1 MeV—a typical case is the Fleischmann-Pons experiment.

which is incomprehensible in the traditional sense. These circumstances cause people to suspect unusual experimental results, which is very natural. However, we should think soberly: Are the experimental phenomena unreliable, or do they not satisfy the experimental conditions actually repeated in the experiment. First, we must clarify why heavy-water electrolysis is required and the palladium cathode absorbs deuterium. What measure of deuteron absorption by the palladium crystal can satisfy the requirement? The experimental phenomena cannot reappear when the inherent law is unclear, and internal conditions have not been satisfied. We cannot mistakenly think this is a negative result.

Energy Spectrum of Burst Neutron Contradicts Traditional Deuteron-Deuteron Fusion Theory

Some people suppose that cold fusion is *d-d* nuclear fusion. According to the *d-d* nuclear fusion equation,

$$d + d \rightarrow {}^4_2\mathrm{He}(0.82\ \mathrm{MeV}) + n(2.45\ \mathrm{MeV}) \quad 50\%$$

and

$$d + d \rightarrow \mathrm{P}(3.02\ \mathrm{MeV}) + T(1.01\ \mathrm{MeV}) \quad 50\% \ , \tag{1}$$

where the characteristic energy of the fusion neutron is 2.45 MeV. However, there are two groups of neutrons that were measured by experiment in which the energy of a group was below 3 MeV, and the other was ~3 to 7 MeV (Ref. 5). It shows that the cold fusion is not *d-d* nuclear fusion, but it may be a new nuclear process.

Tritium-Neutron Yield Ratio Refutes Deuteron-Deuteron Fusion

According to *d-d* fusion equation (1), the yield ratio $T/n = 1$, but the experimental value is $T/n = 10^3$ to 10^9; the difference between the two results is $\sim 10^3$ to 10^9 times. If one thinks that the branching ratio may be changed in cold fusion, then the proton with 3.02 MeV (characteristic energy) should be measured in experiment, and its yield must be equal to tritium. Experiments have not provided this evidence so far.

Contradiction Between Cold Fusion and the Potential Coulomb Barrier

A deuteron requires enough kinetic energy (E_k) to surmount the potential coulomb barrier between two deuterons in *d-d* fusion. If d_f is the distance in which two nuclei can produce fusion, then

$$d_f \leq \gamma_0(A_1^{1/3} + A_2^{1/3}) \tag{2}$$

and

$$E_k = \tfrac{1}{2}mv^2 \geq Z_1 Z_2 e^2/\gamma_0(A_1^{1/3} + A_2^{1/3}) \ , \tag{3}$$

where

$A_1 = A_2 = 2$(mass number of a deuteron)

$\gamma_0 \approx 1.4 \times 10^{-13}$ cm.

The estimated values of kinetic energy E_k in the laboratory system or center-of-mass system are, respectively,

$$E_{k_1} \geq 4 \times 10^5\ \mathrm{eV} \tag{4}$$

and

$$E_{k_c} \geq 1 \times 10^5\ \mathrm{eV} \ . \tag{5}$$

The deuteron must obtain more than 4×10^5 eV energy E_{k_1} from the electrical field if there is accelerated nuclear fusion. But the potential electrical difference is only 10 V in an electrolytic cell experiment, both different on the order of $\sim 10^4$, according to the energy need; it cannot produce *d-d* fusion in the electrolytic cell; and the probability of a deuteron passing through the barrier is $\sim 10^{-74}$ per second at room temperature, but the fusion probability in a cold fusion experiment is $\sim 10^{-17}$ to 10^{-20} per second.[6]

Other "abnormal" nuclear phenomena, such as the "excess heat" phenomenon, cannot yet be explained by *d-d* fusion.

The preceding contradictions indicate that cold fusion may be a new nuclear process, and we cannot understand and review the phenomenon of cold fusion by traditional *d-d* nuclear fusion methods. What was called "abnormal" simply could not be understood in the traditional sense of nuclear fusion.

A POSSIBLE NEW NUCLEAR PROCESS

Contradictions between new phenomena and traditional theory often occur in scientific research. A science develops through the process of exposing contradictions, analyzing, then solving them. The phenomena of cold fusion are incomprehensible, but intense study has provided a clue to the puzzle of cold fusion. There is a possible way around the traditional theory of nuclear fusion.

1. *There is weak interaction in the nuclear force.* It was thought that nuclear force is only a strongly interacting force, but a series of experimental results reveal that there is weak interaction in nuclear force. Yang reviewed 2319 nuclides and found 111 samples of weak interaction of orbital electron capture in unstable nuclides; 673 examples are mixed weak capture; 589 cases are $\beta^{\pm}$ decay; 724 instances are mixed $\beta^{\pm}$ decay. These show the universality of weak interaction in nuclei.

A deuteron is a two-nucleon system. This system also contains weak interaction. A deuteron has a weak force field to capture an electron if the deuteron is excited.

2. *It may exist in the excited state ${}^2_1H^*$ in the ultralow energy range.* Until now, almost all conclusions about deuterons have been based on the following: (a) non-ultralow energy range, (b) the hypothesis that nuclear force is a central force, and (c) nuclear force is a pure, strong interactive force. Some conclusions are, therefore, one-sided.

Vibrational movement exists universally in the nucleus. Vibrational energy levels will appear when the harmonic oscillator potential is considered. If a deuteron is excited by a collision, the deuteron may be in excited state P, or D, or a mixed parity state of states P and D.

The reaction ${}^2_1\mathrm{H}(d,d^*)d^*$ has been detected in the d-d reaction[3,7]; the spin S, isotopic spin T, and the T_3 of the d^* are $S = 0$, $T = 1$, and $T_3 = 0$, respectively. It shows that an excited state of deuterons is possible.

3. *Capturing reaction.*

a. Capturing condition[2,3]:

$$\Delta E = [M({}^2_1\mathrm{H}^*) + m - M({}^2_0N)]C^2 - We \geq 0 \tag{6}$$

and

$$M({}^2_1\mathrm{H}^*) > M({}^2_0\mathrm{H}) \ . \tag{7}$$

The deuteron satisfies the capturing condition, which requires obtaining 0.3 MeV of energy from outside. This energy can be obtained by gathering energy in an electrolytic cell experiment.[2]

b. The capture process is illustrated in Fig. 1.

c. Reacting formula:

$${}^2_1\mathrm{H}^* + e^{-1} \rightarrow {}^2_0N + \nu_e + \gamma \ . \tag{8}$$

d. Fusion reaction process:

$${}^2_0N + {}^A_ZX \rightarrow {}^{A+1}_{\ \ Z}Y + n + Q \ . \tag{9}$$

If a deuteron can be excited by gathering energy to satisfy the capture condition, the excited deuteron can capture an electron and transform a dineutron ${}^2_0N$ to produce deuteron-dineutron fusion or fusion of dineutron and the other nucleus.

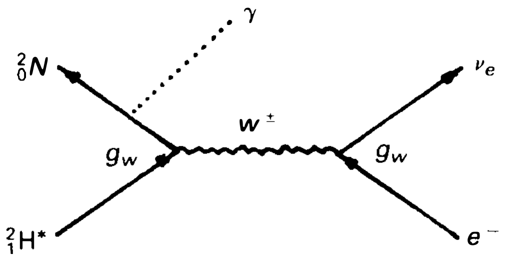

Fig. 1. Feynman diagram of the ${}^2_1\mathrm{H}^*$-e capture process.

A POSSIBLE NEW FUSION

1. This fusion does not have the potential coulomb obstacle. The fusion of dineutron and nucleus can occur at any temperature, and it can surmount many difficulties that are very hard for traditional nuclear fusion theory to overcome. The model appeared for the first time in September 4, 1989, in J. F. Yang's report, "Exploration of Cold Fusion: Deuteron-Dineutron Fusion," presented at a Chinese nuclear physics conference. Teller suggested at a news conference on evaluating cold fusion in October 18, 1989, that a new neutral particle may be catalyzed.

2. ${}^2_0N$-${}^A_ZX$ fusion and the energy distribution of the fusion neutron: In the cold fusion experiment that uses palladium, there probably exist deuteron-dineutron fusion and dineutron-palladium fusion. For example,

$${}^2_0N + {}^2_1\mathrm{H} \rightarrow {}^3_1\mathrm{H}(0.88\ \mathrm{MeV}) + n(2.64\ \mathrm{MeV}) \ , \tag{10}$$

$${}^2_0N + {}^{110}_{46}\mathrm{Pd} \rightarrow {}^{111}_{46}\mathrm{Pd}(0.027\ \mathrm{MeV}) + n(3\ \mathrm{MeV}) \ ,$$

$${}^{111}_{40}\mathrm{Pd} \xrightarrow{\beta^-(2.13\ \mathrm{MeV})} {}^{111}_{47}\mathrm{Ag} + \beta^- + \tilde{\nu}_e \tag{11}$$

$${}^2_0N + {}^{108}_{46}\mathrm{Pd} \rightarrow {}^{109}_{46}\mathrm{Pd}(0.03\ \mathrm{MeV}) + n(3.39\ \mathrm{MeV}) \ ,$$

$${}^{109}_{46}\mathrm{Pd} \xrightarrow{\beta^-(1.028\ \mathrm{MeV})} {}^{109}_{47}\mathrm{Ag} + \beta^- + \tilde{\nu}_e \tag{12}$$

$${}^2_0N + {}^{106}_{46}\mathrm{Pd} \rightarrow {}^{107}_{46}\mathrm{Pd}(0.036\ \mathrm{MeV}) + n(3.77\ \mathrm{MeV}) \ ,$$

$${}^{107}_{40}\mathrm{Pd} \xrightarrow{\beta^-(0.03\ \mathrm{MeV})} {}^{107}_{47}\mathrm{Ag} + \beta^- + \tilde{\nu}_e \tag{13}$$

$${}^2_0N + {}^{104}_{46}\mathrm{Pd} \rightarrow {}^{105}_{46}\mathrm{Pd}(0.04\ \mathrm{MeV}) + n(4.3\ \mathrm{MeV}) \ , \tag{14}$$

and

$${}^2_0N + {}^{105}_{46}\mathrm{Pd} \rightarrow {}^{106}_{46}\mathrm{Pd}(0.064\ \mathrm{MeV}) + n(6.77\ \mathrm{MeV}) \ . \tag{15}$$

The distribution of the energy and relative yield are shown in Fig. 2.

The relative yield is calculated by the normalization method when the D/Pd = 0.85. The calculated results can explain the new experimental phenomenon.[5]

3. Fusion rate:

a. Based on the dineutron model, the fusion rate can be expressed by the product of the forming ratio of a dineutron and the probability of a dineutron-nucleus collision. Our theoretical result is[2,8]

$$P_f \approx 2.77\gamma LmK\ (10^{-22}\ \text{to}\ 10^{-16})/\mathrm{s} \ , \tag{16}$$

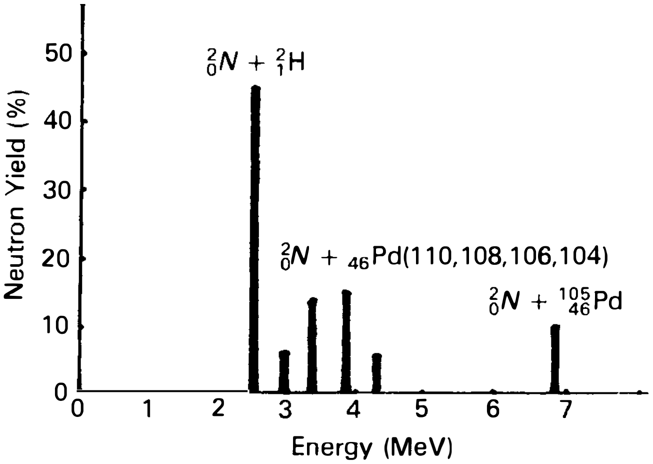

Fig. 2. Neutron energy spectrum of the new fusion.

where

γ = radius of the palladium cathode

L = length of the palladium cathode

m = milliampere number of the deuteron current density

$K \leq 1$

s = second.

If we set $r = 0.2$ cm, $L = 10$ cm, $m = 60$ mA, and $K = 1$, then $P = 3.24 \cdot (10^{-20}$ to $10^{-14})$/s.

b. Theory is compared with experimental results in Table I. All results are within the range of theoretical values.[8]

Using the new processes and new fusion can explain a series of "abnormal" nuclear phenomena. In this paper, we have discussed the contradictions between traditional theory and cold fusion phenomena and suggested that cold fusion may be a new nuclear process. The major objective was to make a few introductory remarks, making it possible for others to come up with valuable opinions. The discussion is primitive. For example, the energy-gathering effect, capture of an excited deuteron by an electron, capture conditions, forming ratio of a dineutron, the fusion ratio, etc., are further discussed in other papers.[3,8]

TABLE I

Experimental and Theoretical Results

Experimenter	Results (fusion/s)	Theoretical Value (This Paper) (fusion/s)
INFN F. Celani et al.	$10^{-19} \div 10^{20}$	$10^{-16} \div 10^{-20}$
M. Fleischmann-S. Pons	10^{-17}	
S. E. Jones	$(3 \div 4) \times 10^{-18}$	

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