Clean Fusion by Tetrahedral and Octahedral Symmetric Condensations

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Abstract: Super screening of Coulomb barrier on deuteron cluster fusion is modeled by formation of quasi-molecular states with electronic quasi-particles under tetrahedral and octahedral symmetric condensations of deuterons in the transient motion of metal-deuteride lattices. Cluster fusion resonates for 4D and 8D fusion processes, of which products are clean (radiation-less) to be major products of ^{4}He with secondary transmutation reactions. Possible reaction branches and products are discussed.

Keywords: 4D fusion, 8D fusion, symmetric condensation, electronic quasi-particle, clean products

1. Introduction

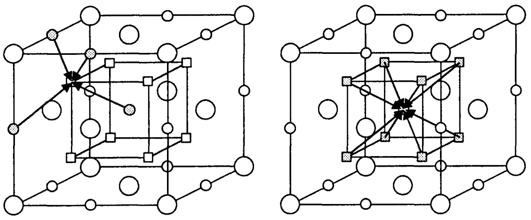
Major claims of experiments for condensed matter nuclear reactions (so called "cold fusion"), such as ^{4}He generation in correlation with excess heat$^{1,2)}$, selective two-alpha-added transmutations$^{3,4)}$, and fission-like products$^{5)}$, can not be attributed to "cold fusion" of known d-d fusion reactions in condensed matter, but can be solely explained by "new reaction theory in condensed matter". Key issues in problems of theorization are; how to construct a consistent theory to explain in linkage of the above major claimed results, and to keep compatibility to already established physics.

We have developed a cluster fusion theory based on the EQPET (Electronic Quasi-Particle Expansion Theory) model$^{6-8)}$, to explain consistently the above major experimental claims. First, we had to look for the possibility of super-screening of Coulomb barrier between deuterons in lattice. We considered transient or dynamic conditions of deuterons and electrons motion in PdDx lattice.

Time-dependent motion of deuterons at O-sites of PdDx was treated as plasma oscillation in lattice harmonic potentials, and focal point in periodical time domain was assumed$^{11)}$. We still use this approximate treatment in the present work. We treat a transient condensate of deuteron cluster at focal point by a steady multi-body cluster with certain life time (more than several fs), and considering the period of lattice plasma oscillation (about 10 to 100 ps) plasma we estimate a relative weight for effective existing time of transient condensate to multiply with fusion rate of steady EQPET molecule.

We looked for the condition that overcame the Thomas-Fermi gas limitation of Coulomb screening by electrons. We assumed in transient motion of deuterons at tetrahedral and octahedral condensations that transient molecular state dde* with electronic quasi-particle e* could be formed under symmetric condensation conditions that are some kind of dynamic Bose-type condensation. Focal points of deuteron cluster were imagined in T-sites of PdD full loaded lattice (TSC: tetrahedral symmetric condensation) and O-sites of PdD_2 overloaded lattice (OSC: octahedral symmetric condensation), as shown in **Fig.1 (a) and (b)** respectively, and in some defects or deformed lattice points at grain boundaries. Speculated mechanisms are: D-cluster fusion in lattice dynamics produces 23.8MeV two ^{4}He-particles in 180 degree opposite directions and/or 47.6MeV two ^{8}Be-particles in 180 degree opposite directions, per 4D and/or 8D fusion respectively. Transmutation reactions including fission may take place as secondary reaction of these high-energy particles with lattice metal nuclei.

This paper treats first to briefly summarize the EQPET model for TSC and OSC conditions. Then discussions are extended to estimate power levels of deuteron cluster fusion reactions, possible branches of outgoing channels with characteristic products (particles) and quality of clean fusion process. Discussions are also given comparing results of the present model and experimental results by Krabut9) and Iwamura4).


(a) (b)

○ Palladium ○ Octahedral site□ Tetrahedral site

Fig.1: Tetrahedral (a) and octahedral (b) condensation of deuterons in PdDx

2. Deuteron Cluster Fusion

Model example of deuteron cluster fusion was proposed as the Tetrahedral Symmetric Condensation (TSC) and the Octahedral Symmetric Condensation (OSC) in PdDx lattice dynamics. As illustrated in Fig.1, TSC may take place at locally full loaded PdD regions (x=1.0), while OSC may happen much more difficultly at locally overloaded PdD_2 regions (x=2.0). As discussed later on power level, we only need to require local density of 1E-6 times (ppm order) of Pd density for the OSC condition, while much higher local density, e.g., 10 % of Pd atomic density is required for the TSC condition. To generate electronic quasi-particle states, basic mechanism is thought to be the dynamic formation of quadruplet deuteron molecule, which is an **orthogonal coupling of two D_2 molecules**, as illustrated in **Fig.2**.

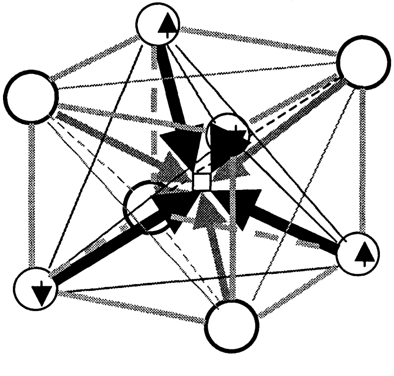


Fig.2: TSC, bigger circles for deuterons and smaller circles with arrow (spin) for electrons

Three-dimensional motion of TSC can be converted to two-dimensional motion using momentum vector conversion10). A two dimensional view of TSC is shown in **Fig.3**. To minimize total energy of the system, charge neutral condensation in average of 4D cluster (4 deuterons with alternately coupled 4 electrons with anti-parallel spins for counter-part electrons with reversed momentums) may cause the central point (T-site in this case) condensation from 4 O-sites of deuterons and 4-sites of electrons. Hence, transient condensate of electrons, namely quadruplet e*(4,4) may be formed at around the central T-site.

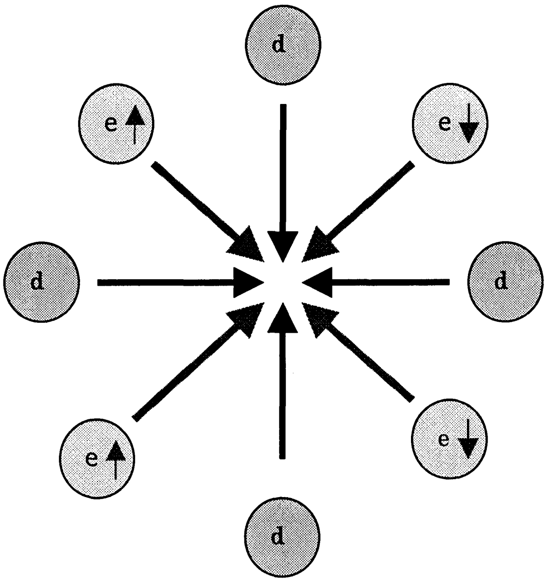


Fig.3: Two-dimensional view of TSC, plus charge for d, minus charge for e

We assume a similar condition for the OSC motion, as illustrated in **Fig.4**. When 4 electrons down-spins are happening to be arranged on upper half together with 4 electrons up-spins on lower half, averaged charge neutral condensation from 8 T-sites to the central O-site may become possible, to form 8D cluster with an octal-coupling state e*(8,8) of electrons at around the central O-site. This condition may realize super-screening for virtual d-d pairs in the 8D cluster, and 8D fusion rate can be calculated by the rapid cascade reaction model, i.e., D+(D+(D+(D+(D+(D+(D+D))))))8,10).

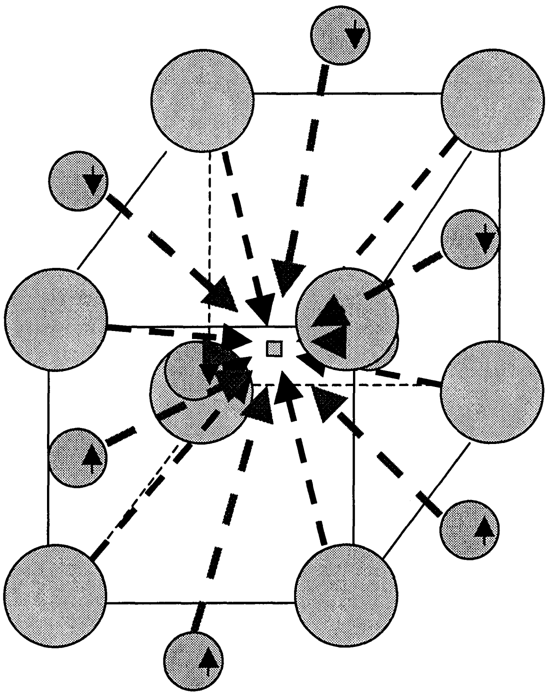


Fig.4: OSC (octahedral symmetric condensation), larger circles for deuterons, smaller circles with arrow (spin) for electrons

3. EQPET Model

A 4D cluster under TSC condition will cause 2D, 3D, and 4D nuclear fusion in competition, because the TSC state reflects the atomic level motion of deuterons in condensed matter and does not necessarily relate to 4D nuclear fusion reaction as strong interaction. In the same way, an 8D cluster causes the competition process of nuclear fusion reactions between 2D, 3D, 4D and 8D nuclear fusion reactions. We need therefore to define and estimate modal fusion rates to TSC and OSC processes8). Modal fusion rates are defined as:

$$\lambda_{2d} = a_1^2 \lambda_{2d(1,1)} + a_2^2 \lambda_{2d(2,2)} \qquad (3.1)$$

$$\lambda_{4d} = a_1^2 \lambda_{4d(1,1)} + a_2^2 \lambda_{4d(2,2)} + a_4^2 \lambda_{4d(4,4)} \qquad (3.2)$$

$$\lambda_{8d} = a_1^2 \lambda_{8d(1,1)} + a_2^2 \lambda_{8d(2,2)} + a_4^2 \lambda_{8d(4,4)} + a_8^2 \lambda_{8d(8,8)} \qquad (3.3)$$

Here values for $\lambda_{nd(m,m)}$ as intrinsic microscopic fusion rates are defined and calculated for dde*(m,m) transient molecular sates7),and extended to multi-body fusion rates assuming rapid cascade barrier penetration and multi-body strong interactions6-8,10). These values are given in Table-1 of reference-8.

Screened Coulomb potentials for dde* EQPET molecules were calculated by the variation method of quantum mechanics7), to be given as the following equation:

$$V_s(R) = e^2/R + V_h + (J + K)/(1 + \Delta) \qquad (3.4)$$

On the right hand side of equation (3.4), the first term is the bare Coulomb potential and the second and third terms reflect in the screening effect by e*, which are the measure of "simply defined screening energy", as many experimentalists often use. In **Table-1**, effective screening energies for dde* EQPET molecules are listed up. We see that screening effects by e*(4,4) · and e*(8,8) are very strong, in comparison with that a muon (mass is 208 times of electron mass) works between effects of e*(4,4) and e*(8,8). Thus, EQPET molecules may realize super screening of Coulomb potential.

Table-1: Effective screening energy of dde* molecule

e*	dde*	dde*e*
(1,1)	-14.87 eV	-30.98 eV
(2,2)	-260 eV	-446 eV
(4,4)	-2,460 eV	-2,950 eV
(8,8)	-21 keV	-10.2 keV

In equations (3.1) through (3.3), coefficients a_1 through a_8 are estimated by evaluating total wave function Ψ for deuteron cluster with electrons which is expanded by wave functions Ψ(m,m) of quasi-molecular states to dde*(m,m) as,

$$\Psi = a_1\Psi(1,1) + a_2\Psi(2,2) + a_4\Psi(4,4) + a_8\Psi(8,8) \qquad (3.5)$$

In reference-8, approximate values of a_1 through

a_8 were given by taking simple quantum mechanical statistics for electron spin arrangement in TSC and OSC conditions. Calculated modal fusion rates are shown again in **Table-2**.

Table-2: Modal fusion rates for TSC and OSC

TSC(tetrahedral)	OSC(octahedral)
λ_{2d} = 1.8E-21 f/s/cl	λ_{2d} = 7.9E-22 f/s/cl
λ_{3d} = 1.5E-13 f/s/cl	λ_{3d} = 3.5E-13 f/s/cl
λ_{4d} = 3.1E-11 f/s/cl.	λ_{4d} = 7.0E-11 f/s/cl
	λ_{8d} = 7.8E-4 f/s/cl

Table-3: Power level of 4D and 8D fusion rates

Item	TSC(tetrahedral)	OSC(octahedral)
density	1E22 cl/cc	1E16 cl/cc
power	3 W/cc	78 W/cc
neutron	10 n/s/cc	<1 n/s/cc

4. Products and Power Level of Cluster Fusion

Using modal fusion rates in Table-2, we estimated power levels of multi-body fusion rates for assumed deuteron cluster densities, as shown in **Table-3**. Height of periodical harmonic potential for deuteron in PdDx lattice is known to be 0.22 eV, so that 0.22 eV of deuteron (plasmon phonon) energy corresponds well to excited states of trapped deuterons for dynamic motion in PdDx lattice potentials. Under this excitation condition, all deuterons trapped at O-sites move to the central T-site, and we estimate roughly the average TSC cluster density to be on the order of 1E22 clusters per cc. In this condition, we get power level by 4D fusion rate to be 3 W/cc (3E11 f/s/cc) and 10 n/s/cc neutron production rate by 2D fusion. Therefore, neutron production rate is very small as on the 1E-10 order of ^{4}He production rate by 4D fusion.

The OSC condition requires local PdD_2 lattice of overloaded condition, so that we assume here the OSC cluster density is very low as 1E16 clusters/cc (namely 1 ppm level of Pd atom density). Under this condition, we have still surprisingly high power level as 78 W/cc (8E12 f/s/cc) by 8D fusion rates, which produce two high-energy ^{8}Be particles per fusion.

We have speculated that 4D TSC fusion generates two 23.8 MeV ^{4}He-particles in 180 degree opposite directions as:

$$4D \rightarrow {}^8Be^*(47.6\ MeV) \rightarrow {}^4He + {}^4He + 47.7\ MeV \qquad (4.1)$$

However, we have at least once to consider the following possible branches of outgoing channels of threshold reactions for ^{8}Be(ground state) break-ups.

$$^8Be(g.s.) \rightarrow {}^4He + {}^4He + 91.86\ keV \qquad (4.2)$$

$$\rightarrow {}^3He + {}^5He(n + {}^4He) - 11.13\ MeV \qquad (4.3)$$

$$\rightarrow t + {}^5Li(p + {}^4He) - 21.68\ MeV \qquad (4.4)$$

$$\rightarrow d + {}^6Li - 22.28\ MeV \qquad (4.5)$$

$$\rightarrow p + {}^7Li - 17.26\ MeV \qquad (4.6)$$

$$\rightarrow n + {}^7Be - 18.90\ MeV \qquad (4.7)$$

Other channels than (4.2) are threshold reactions with high threshold energies. Therefore, we have regarded these threshold reactions as minor channels with very small branching ratios, even with high-excited energy state of (4.1). Another possibility of minor channels in relation of (4.1) is break ups from excited states of ^{4}He which may break up to n + ^{3}He or t + p channels as those for 2D fusion. We regard branching ratios to these minor channels are also small, due to very steady core of alpha-clusters of ^{8}Be nucleus.

For 8D fusion, we can make a similar discussion that alpha-clustered channels dominate.

$$8D \rightarrow {}^{16}O^*(109.84\ MeV) \rightarrow {}^8Be + {}^8Be + 95.2\ MeV \qquad (4.8)$$

$$\rightarrow {}^{12}C + {}^4He + 50.12\ MeV \qquad (4.9)$$

The lifetime of ^{8}Be(g.s.) is very short as 6.7E-17 s to break up to two alpha particles. Consequently, major products of 4D and 8D fusion are primarily high-energy (23.8 MeV in kinetic energy) alpha particles. The slowing down and ionization process by 23.8 MeV alpha-particles in PdDx condensed matter has very small cross section to emit K-alpha X-rays (22 keV) from Pd K-shell electron ionization. Major source of X-ray emission is speculated to the bremsstrahlung continuous X-rays in the region less than 3 keV by convey electrons, which are hard to observe, due to attenuation in experimental cells. Thus energy deposit by 23.8 MeV alpha particles becomes apparently radiation-less, namely "clean".

5. Secondary Reactions

High-energy (23.8 MeV) alpha particles by 4D fusion can induce secondary nuclear reactions with host metal nuclei as the following capture reactions,

$$^{105}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{109}\text{Cd}^{*}(1.27\text{ y}) \qquad (5.1)$$

$$^{106}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{110}\text{Cd} \qquad (5.2)$$

$$^{108}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{112}\text{Cd} \qquad (5.3)$$

$$^{110}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{114}\text{Cd} \qquad (5.4)$$

$$^{107}\text{Pd}(6.5\text{E}6\text{ y}) + {}^{4}\text{He} \rightarrow {}^{111}\text{Cd} \qquad (5.5)$$

Impurity Cd production rates in Pd cathode in the deuterium gas glow-discharge experiments by Karabut[9)] may be explained by the above secondary reactions. Fission-like products also reported by Karabut[9)] and Mizuno[5)] can be explained by alpha-particle-induced fission process as reported by Ohta[12)] in this meeting.
Even within short life of high energy ^{8}Be-particles by 8D fusion, more than 10 metal nuclei exist within the range and we expect capture reactions as,

$$\text{M}(A,Z) + {}^{8}\text{Be} \rightarrow \text{M}(A+8, Z+4) + Q \qquad (5.6)$$

The kinetic energy 47.6 MeV of ^{8}Be by 8D fusion is well over the Coulomb barrier height 30.1 MeV for ^{133}Cs + ^{8}Be to ^{141}Pr reaction. Due to the liquid-drop collision-like capture process of this reaction, kinetic energy of ^{8}Be will be transferred to kinetic energy of compound nucleus M(A+8, Z+4).
Selective nuclear transmutations reported by Iwamura[3,4)] can be explained by this process, although we have few problems of possible radiation (gamma rays) emission in the process, which we will discuss elsewhere .

6. Conclusions

The EQPET model was proposed to explain super-screening for d-d pairs in condensed matter. Deuteron cluster fusion dominated will however take place by TSC and OSC conditions to make resonance multi-body fusion reactions for 3D, 4D and 8D strong interactions. Helium-4 is the major product, and neutron production rate is very small on the order of less than 1E-10 of helium production rate. High-energy alpha particles by 4D and 8D fusion reactions will induce secondary transmutation reactions with host or mounted heavy nuclei. Slowing down of high-energy alpha particles as products of 4D and 8D fusion reactions may emit low energy continuous X-rays which are difficult to observe from outside of experimental cells. We can say that deuteron cluster fusion in condensed matter is clean or almost radiation-less.

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