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DEUTERIDE-INDUCED STRONG FORCE REACTIONS

Talbot Chubb A. and Scott Chubb R.
Oakton International Corporation, Oakton, VA, USA

N_D band state D^+ ions are treated as a sum over pairs. The wave functions of a D^+ pair is assumed to be a product of a Bloch function in lattice space times a Bloch function in separation space. Overlap allows a strong force fusion reaction to $^4He^{++}$. A coupling between the nuclear change and the ion charge distribution in the lattice is described. The change in ion charge distribution scatters Bloch electrons in a multistep nuclear de-excitation process.

The question as to whether radiationless fusion of the Fleischmann and Pons (1989) type can be explained by solid state physics depends on the answers to a number of questions. How does the symmetry of an external environment affect an embedded physical system? How perfect does the external symmetry have to be to have an effect on a system embedded in a metal crystal? At what point does a transition from a molecularly configured ion to a periodically configured ion occur? How strong does the self-repulsion between ions in a many-body state have to be to destroy the many-body configuration? Over how large a volume can a periodically configured ion maintain coherence? More particularly, can a deuteron in a periodic configuration maintain coherence over a volume of 20 x 20 x 20 unit cells, i.e. over nanometer scales? How different are the thermodynamic properties of PdD_x crystals of nanometer size from those of the bulk deuteride? Can there be a coupling between a nuclear process with a Planck time of 10^{-22} s and an electron process with a Planck time of 10^{-13} s? What dissipation modes exist inside an electron fermi sea that do not exist in free space?

Individual physicists have presented their opinions about some of these questions. Leggett and Baym (1989) have stated "Possible intrinsic sources of enhancement of the fusion rate include ...... an exotic mechanism relying on coherence between fusion processes involving different deuteron pairs". After calculating a fusion rate based on tunneling they say "For the case of many deuterons at T=0 our result shows that the necessary (reaction rate) enhancement (for fusion) .....would require at a minimum very exotic long-range influences on the tunneling process." Anderson (1972) has said "The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. " This statement is applied to the broken periodic symmetry that distinguishes chemistry from the solid state physics of lattice systems. Joannopoulos (1998) in reviewing a paper says "Bloch's theorem for an interacting 'many'-body system does not imply periodicity in r_{12}". Here, r_{12} is the separation between 2 deuterons in center-of-mass, separation coordinates. Periodicity with respect to r_{12} must exist if radiationless fusion is to occur by solid state physics. Schwinger (1994) has said "in very low energy cold fusion one deals essentially with a single state, or wave function, all parts of which are coherent." He also said ". . . in contrast with the vacuum, the lattice is a dynamical system, capable of storing and exchanging energy." Arata and

Zhang (1995) have said "Especially, it is well known that [D*]=1 should instantaneously be achieved in the "cluster" (<100 Å in diameter)[9]. Consequently, characteristics of the deuterium absorption and its variation with pressure are greatly dependent on S*". Here [D*] is D/Pd , and S* is surface area/volume. Arata and Zhang's Reference [9] is to Fujita (1994). Of the above, only statement (Joannopoulos, 1998) is incompatible with theory presented in this paper.

The opinions expressed above are worth serious consideration. However, the ultimate arbiter is an appeal to nature by experiment.

Radiationless fusion of deuterium into ^{4}He is understandable within the structure of ion band state theory (Chubb and Chubb, 1991, 1996a, 1996b; Sada, 1997), in which some of the deuterons present in the metal assume the periodic symmetry of the lattice. They become Bloch function-deuterons. The theory assumes that:

1. Atom-cluster-size ordered volumes in a metal become occupied by a small number of coherent Bloch deuterons at elevated deuterium chemical potential.

2. At low band state concentration the many-body wave function (Chubb and Chubb, 1991) can be treated as a sum over a set of paired deuterons, which we call di-deuterons.

3. The 2-particle wave equation for the di-deuterons is a 6-dimension version of the Schroedinger equation, and has periodic symmetry in both physical space and separation space. The point character of each of the 2 deuterons is partitioned into N_{cell} unit cells in separation space.

4. The delocalized deuterium occupies physical space already filled with the delocalized electron matter of the partially filled conduction band, so that:

    - The band state deuterons are dressed, i.e. neutralized in each unit cell

    - Any sudden change in the di-deuteron charge distribution excites electron transitions in the partially filled conduction band

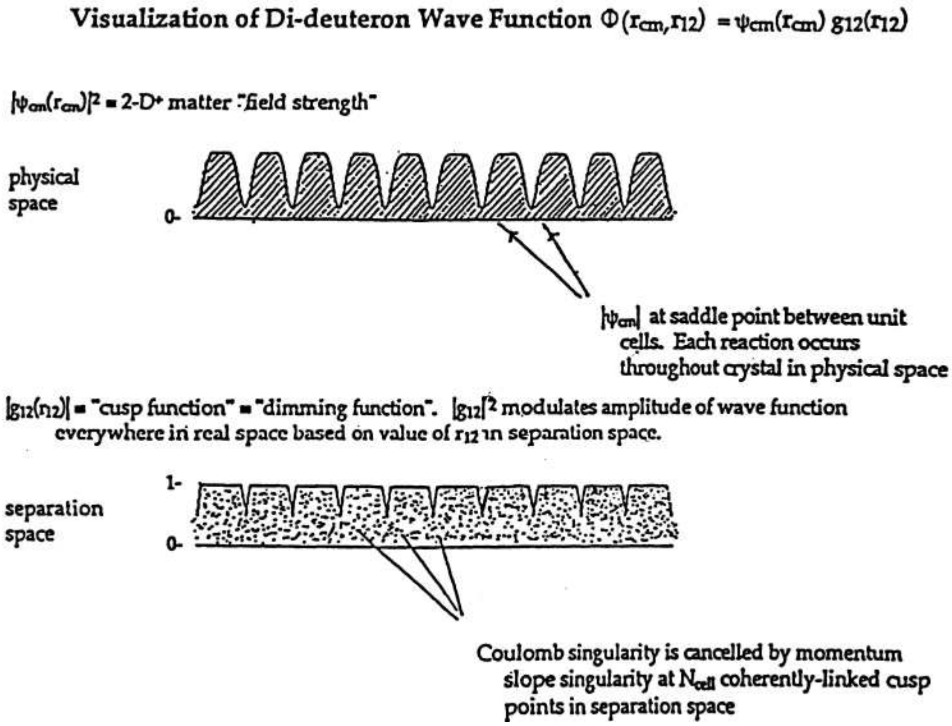


Figure 1

In Figure 1 we focus on an atom cluster of the Fujita type in which there are several Bloch deuterons occupying a common band state. These deuterons see primarily the periodic electrostatic potential established by the metal atoms. They form a many-body system analogous to that formed by electrons in the metal. This system can be approximately modeled as a sum over paired deuterons. The paired deuterons see both the periodic lattice and a mutual dd Coulomb repulsion. If the self-interaction repulsion is neglected, they have complete wave function overlap. If the repulsion is gradually turned on, the 2-particle wave function develops cusps in separation space. It is our view that these cusps in separation space must have the same periodic symmetry that characterizes all Bloch functions. As illustrated in the picture, the 2-particle wave function is a function of 6 dimensions, 3 dimensions of physical space and 3 dimensions of separation space. The full implementation of Bloch symmetry requires that there be N_{cell} cusps in separation space.

The 2-particle wave equation that produces the above type of wave function is the following:

$$\left\{ -\frac{\hbar^2}{4m} M_{cm}{}^2 + (2e)U_{lattice}(\mathbf{r}_{cm}) - \frac{\hbar^2}{m} M_{12}{}^2 + \sum_{\substack{j=1 \\ \text{coherent} \\ \text{volume}}}^{N_{cell}} e^2/(N_{cell}{}^2 (r_{12} - \mathbf{R}_{12_j})) \right\} \Phi(\mathbf{r}_{cm},\mathbf{r}_{12})$$

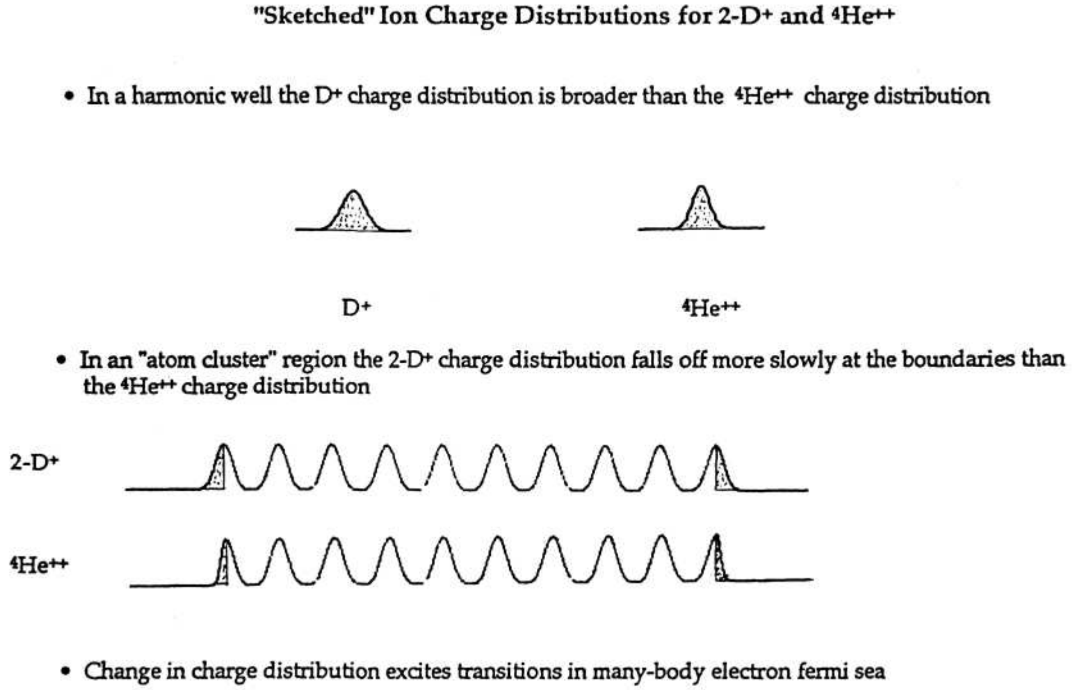
$$= E\, \Phi(\mathbf{r}_{cm},\mathbf{r}_{12}) \quad ,$$

where $U(\mathbf{r}_{cm})$ is the lattice potential per unit charge, $\mathbf{r}_{cm}$ is the position vector in physical space, and $\mathbf{r}_{12}$ is a vector separation parameter in separation space. $\mathbf{r}_{cm}$ and $\mathbf{r}_{12}$ are related to vectors $\mathbf{r}_1$ and $\mathbf{r}_2$ of configuration space by $\mathbf{r}_1 = \mathbf{r}_{cm} + \frac{\mathbf{r}_{12}}{2}$ and $\mathbf{r}_2 = \mathbf{r}_{cm} - \frac{\mathbf{r}_{12}}{2}$, and $\Phi(\mathbf{r}_{cm},\mathbf{r}_{12})$ is a 6-dimension "Bloch function" with independent lattice vectors $\mathbf{R}_{cm_i}$ and $\mathbf{R}_{12_j}$ such that

$$|\Phi(\mathbf{r}_{cm} + \mathbf{R}_{cm_i}, \mathbf{r}_{12})| = |\Phi(\mathbf{r}_{cm},\mathbf{r}_{12})|$$

$$|\Phi(\mathbf{r}_{cm},\mathbf{r}_{12} + \mathbf{R}_{12_j})| = |\Phi(\mathbf{r}_{cm},\mathbf{r}_{12})| \qquad .$$

Note that $\Phi(\mathbf{r}_{cm},\mathbf{r}_{12})$ has N_{cell} singularities in separation space. The normal treatment of correlation assigns only one singularity to separation space (Joannolpoulos, 1998). When there are N_{cell} singularities, the Coulombic repulsion disappears at large N_{cell}. This reduction in Coulombic repulsion allows singlet deuteron pairs to coalescence into a Bloch function ^4He configuration. The reaction is $D^+_{Bloch} + D^+_{Bloch} \times {}^4He^{++} + 23.8$ MeV. Coalescence fluctuations are a requirement for the cold fusion reaction. The existence of cold fusion heat is a test of the applicability of full Bloch symmetry to the correlation interaction in periodic systems.

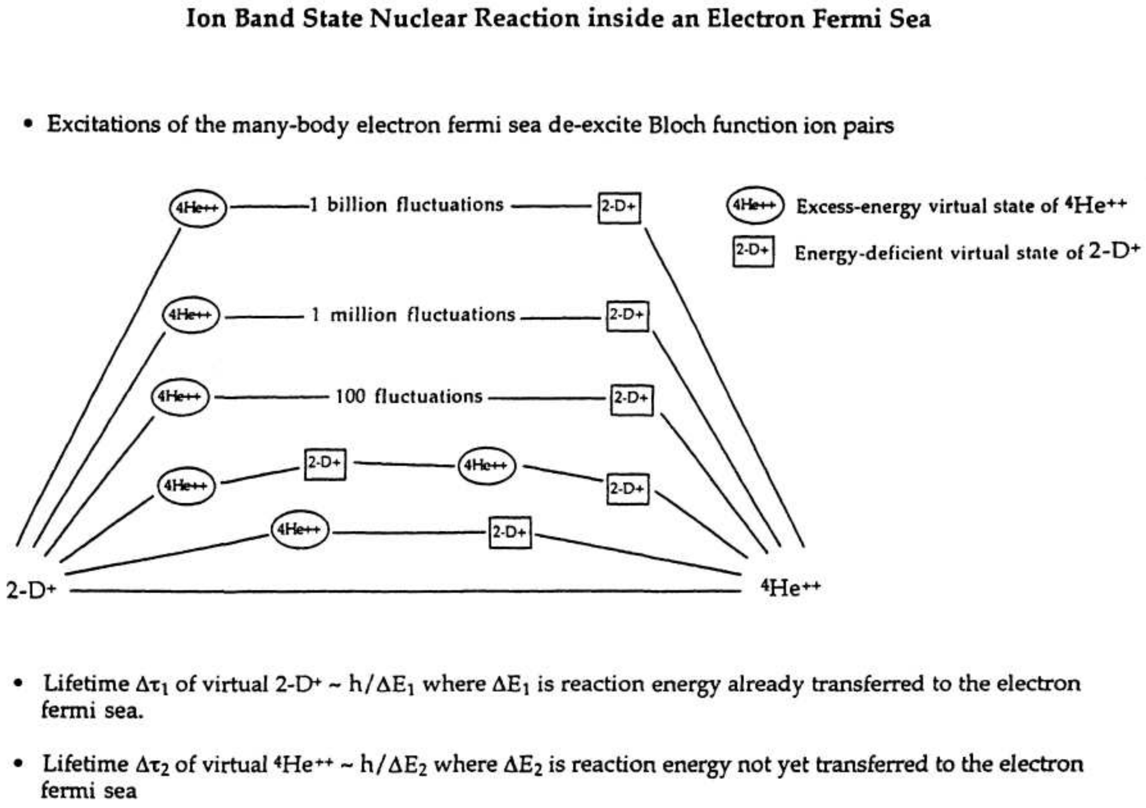


"Sketched" Ion Charge Distributions for 2-D^+ and $^4He^{++}$

- In a harmonic well the D^+ charge distribution is broader than the $^4He^{++}$ charge distribution
- In an "atom cluster" region the 2-D^+ charge distribution falls off more slowly at the boundaries than the $^4He^{++}$ charge distribution
- Change in charge distribution excites transitions in many-body electron fermi sea

Figure 2

Coalescence fluctuations, which occur on the 10^{-22} s timescale, do not necessarily lead to fusion reactions. There must also be a coherent coupling between the nuclear change and the electrostatics of the lattice system. This coupling occurs because the distribution of ion charge is affected by the nucleus mass through a change in zero point motion. The top line in Fig. 2 shows the difference in charge distribution for D^+ and $^4He^{++}$ which would occur for the unphysical case of coalescence of 2 interstitial D^+ in an isolated harmonic well. The distributions show the effect of a change from mass 2, charge 1 to mass-4, charge 2. The pertinent case of coherent Bloch-function ions in an atom cluster is shown at the bottom of the figure. The charge distribution in the interior of the cluster is unchanged by the fluctuation. Instead the change occurs in the boundary region beyond the classical turning point (shaded region) where ion coherence is lost.



Ion Band State Nuclear Reaction inside an Electron Fermi Sea

- Excitations of the many-body electron fermi sea de-excite Bloch function ion pairs

- Lifetime $\Delta\tau_1$ of virtual 2-D$^+$ ~ $h/\Delta E_1$ where ΔE_1 is reaction energy already transferred to the electron fermi sea.
- Lifetime $\Delta\tau_2$ of virtual ^{4}He^{++} ~ $h/\Delta E_2$ where ΔE_2 is reaction energy not yet transferred to the electron fermi sea

Figure 3

Fig. 3 shows how the band state ion plus the electrons of the partially filled conduction band respond. The electrostatic change is small, but it is capable of exciting a few transitions in the electron fermi sea. It seems impossible that a single fluctuation could remove 23.8 MeV from the nuclear system. However, if even a fraction of an eV is transferred to the electron system, conservation of energy means that the nuclear system cannot permanently return to the 2-deuteron state. It can only return to a virtual state limited by its Planck time. A sequence of fluctuations and associated electron excitations must then occur until the entire 23.8 MeV of reaction energy is transferred to the electrons. The typical single-step nuclear reaction is replaced with a high order sequential relaxation, as illustrated in this sketch. The $\delta(E_i - E_f)$ factor in the development of the Fermi Golden Rule allows an interval during which conservation of energy is violated in accord with the uncertainty principle. During this period of energy transfer back and forth fluctuations as in Fig. 3 occur.

The physical processes described above are allowed by conventional quantum theory. The assumption that the di-deuteron wave function is a Bloch function in separation space is novel, but consistent with the typically used configuration co-ordinate representation of 2 independent Bloch deuterons in that the assumed expression transitions into the latter seamlessly as the interaction potential is reduced. The reaction process which includes transfer of energy to electrons is also novel in that it is a very high order process, but one that violates no quantum mechanical principle. The whole process is radiationless and produces ^{4}He as observed by Arata and Zhang (1996, 1997) and by Miles and Bush (1993)

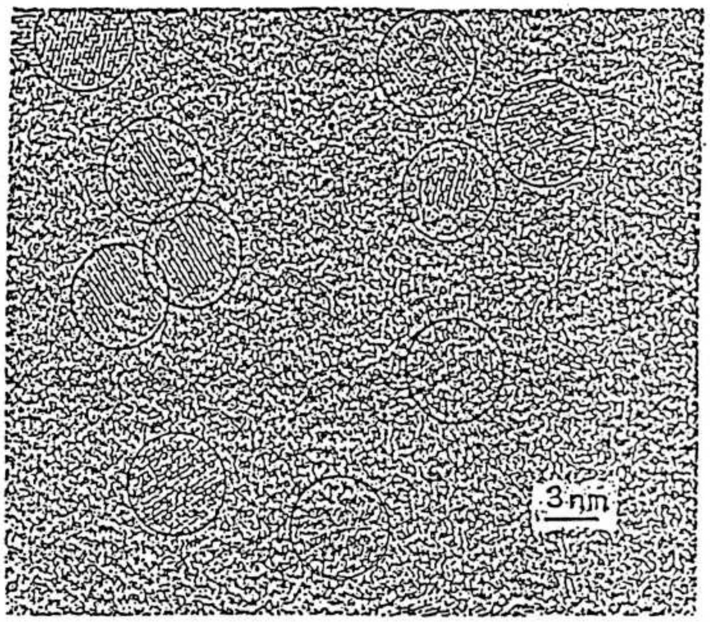


Figure 4

Figure 4 is a Fujita (1994) electron microscope photo of an amorphous solid containing ordered atom clusters 1000 - 100000 unit cells in volume. The Arata and Zhang DS-cathode studies have used Pd powders of 0.04 and 0.4 micron size. We think that Fujita type atom clusters may be able to form in these powders in the same manner as in amorphous solids. Fusion energy release in ion coherent regions as small as the Fujita clusters would be expected to destroy the cluster. However, the Ion Band State Theory says that the nuclear energy goes into the Bloch electrons, not the ions. Since the Bloch electrons have larger coherent volumes than the Bloch ions, the lower limit to useful ion coherence volume may be set by the requirement for wave function overlap.

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