# Ion Band State Fusion

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ABSTRACT

Puska et al.[6] and Astaldi et al.[1] have provided experimental evidence for the existence of hydrogen ion band states in adsorption studies of H and D atoms on metallic surfaces. If a certain view of quantum reality is correct, an ion band state (IBS) $D^+$ population has wave function overlap and will undergo cold fusion, unlike normal molecules and ionic and covalent solids. Arguments leading to this conclusion and a tabulation of likely IBS reactions are presented.

## 1. Introduction

IBS fusion assumes a population of energetically-bound band state deuterons. IBS wave function amplitudes have the periodicity of a lattice. The postulated band state is a 3-dimensional analog of the surface $H^+$ and $D^+$ band states observed by Puska et al.[6] and Astaldi et al.[1]. The many body wave function describing a $D^+$ IBS population and its nuclear self-interaction properties are described in Chubb and Chubb[3,4]. The theory predicts reactions which release volume-distributed heat, whereas reactions involving energetic particle emission are forbidden. This paper discusses why and how fusion can occur with a $D^+$ IBS population and explains why it is not allowed in normal, deuterated chemical compounds.

## 2. Self-interaction Reactions in Bound Systems

Quantum mechanics describes IBS reactions in terms of a summation over energy-conserving configuration fluctuations (partial reactions) $\dot{N}$ between an initial state $\langle AB|$ and a transitory state $|C\rangle$, namely $\dot{N} = 2\pi/\hbar \langle AB|V|C\rangle\langle C|V|AB\rangle\delta(E_{AB}-E_C)$, where $\hbar$ is Planck's constant/$2\pi$, V is the (primarily nuclear) interaction Hamiltonian, $E_{AB}$ and $E_C$ are ISB

FRONTIERS OF COLD FUSION

initial and transitory state energies, and $\delta$ is the Dirac delta function. On a longer time scale $|C\rangle$ can interact electromagnetically and irreversibly with the lattice through excitation of electrons and/or phonons. When V involves short range forces, finite $\hat{N}$, requires that on the scale of atoms the spatial part of the input-state wave function $\psi_A\psi_B$ must overlap $\psi_C$ and spatial part $\psi_A$ must overlap $\psi_B$. Self-induced reactions may occur, depending on the correlation properties of the bound system wave function. The wave function is determined by system energy minimization subject to the electromagnetic interactions between particles and system boundary conditions. Consider the helium atom, which consists of the $He^{++}$ nucleus and the two electrons. The energy minimizing solution for the helium electrons is given, to adequate accuracy for our purposes, by the Hylleraas second approximation.[7] With the position of the nucleus being coordinate system origin, the 2-electron wave function consists of a main term, which describes the fall-off of electron charge density with radial distance r, and two correlation factors which modulate the main term so as to reduce the wave function amplitude when $\mathbf{r}_1 \approx \mathbf{r}_2$. Here $\mathbf{r}_i$ is the position vector of electron$_i$. The correlation terms dimple the wave function at $\mathbf{r}_1 \approx \mathbf{r}_2$, reducing electron-electron overlap. In the helium, atom these dimpling factors are small and the overlap is almost complete. If the electrons had the nuclear properties of deuterons, cold fusion would occur.

3. Non-applicability of Gamow Calculations for Bound Particles

It is instructive to calculate the expected overlap of the two electrons of the helium atom using the Gamow factor[5] $G_e$. The wave function overlap is proportional to $(G_e)^{1/2}$, where

$$G_e = \exp(-2\pi\alpha\, c/v(T)) \qquad (1)$$

Here $\alpha=1/137$ is the fine structure constant, c is the speed of light and v(T) is the relative speed of electrons (=twice the thermal speed of the single electron) at temperature T, defined by $v(T) = (6K_BT/m_e)^{1/2}$. $K_B$ is the Boltzmann constant and $m_e$ is the electron mass. Using $K_BT \leq .025$ eV, one finds $G_e \leq 10^{-37}$, whereas the correct value is near unity.

4. Why Deuterated Compounds Don't Fuse

The 2-electron wave function of the helium atom is calculated using the principle of energy minimization. More generally, for bound systems involving particles of mass m the kinetic energy density is $\hbar^2|\nabla\psi|^2/(2m)$ and the potential energy density associated with particle$_i$-particle$_j$ repulsion is $e^2|\psi_i|^2|\psi_j|^2/2r_{ij}$, where $|\psi_i|^2$ is the particle density of particle$_i$ and $r_{ij}$ designates $|r_i-r_j|$. Dimpling reduces the wave function as $r_{ij} \to 0$, decreasing potential energy but increasing kinetic energy. The amplitude of the correlation dimpling modulation is the value at which the incremental decrease in potential energy equals the incremental increase

in kinetic energy. In the Hylleraas atom, this balance is achieved with very small dimpling, i.e. large overlap.

However, the balance condition would be very different if the electrons of the helium atom had the mass of $D^+$, while the size of the helium atom were kept unchanged. Here the increase in kinetic energy for a fixed amount of correlation dimpling is reduced by 3700 relative to the real atom, while the potential energy reduction is unchanged. Energy minimization then occurs with 100% dimpling, i.e. $\psi = 0$ at $r_{12} = 0$ for all r. This example illustrates the reason why nucleus-nucleus overlap does not occur for any deuterated molecule or ionic or covalent solid. Here, the volume of the molecule or solid is set by the deBroglie wavelength of the electrons while the wave-function dimpling of the nucleus-nucleus interactions is set by the nuclear masses. For the nucleus wave functions, correlation dimpling is complete and no nucleus-nucleus overlap occurs. In chemical substances cold fusion is impossible.

## 5. The Quantum Reality Question for Ion Band State Matter

The possibility of cold fusion depends on the correlation behavior of IBS matter. The wave function of low density electron band state matter describes particles whose charge is partitioned over the many unit cells $N_{cell}$ of a crystal, i.e. the matter state is built from Bloch functions. If $D^+$ IBS matter acts as if the charge of each $D^+$ ion is similarly partitioned over $N_{cell}$, the charge within each unit cell is $e/N_{cell}$. The coulombic correlation energy density associated with each pair$_{ij}$ of band state $D^+$ in a given unit cell then is $e^2|\psi_i|^2|\psi_j|^2/(2r_{ij}N_{cell}^2)$. In the sum over $N_{cell}$, this interaction is much smaller than the comparable $e^2|\psi_i|^2|\psi_j|^2/2r_{ij}$ interaction of the chemical case. Here $\psi_i$ designates a single particle wave function contribution to the many body wave function. The ratio $|\nabla\psi_i|/|\psi_i|$ is independent of $N_{cell}$. The net effect is that the relative contribution of the kinetic energy increase through dimpling is multiplied by the factor $1/N_{cell}$. Energy minimization then occurs with negligible dimpling, as in the helium atom. With this picture of quantum reality there is no correlation barrier to cold fusion.

## 6. Band State Fusion

The reactions of $D^+$ ion band state fusion are of a different character than those of free particle fusion. $D^+$ ion band state matter is a volumetrically-distributed, collective, exchange-dominated, bosonic matter state described by a many body wave function with Bloch-function symmetry[2]. The mass distribution within each unit cell corresponds to the zero point motion of a $D^+$ ion in the potential well provided by the lattice. The allowed reactions are transitions from $D^+$ ion band state matter to other band state matter of the same geometry, preserving the same Bloch symmetry. The reaction possibilities are most easily identifiable if the many body wave function is expressed in terms of transient integer particle occupations of unit cells, as described in the Wannier function representation[4]. This representation contains terms which describe

transient multiple occupations, which we designate n-$D^+_{band}$. The 2-$D^+_{band}$ undergoes reversible reactions 2-$D^+_{band} \rightleftarrows {}^4He^{++*}_{band}$, in which ${}^4He^{++*}_{band}$ is heliumlike IBS matter with energy = 23.8/Ncell MeV. To preserve periodic order, on a longer time scale ${}^4He^{++*}_{band}$ decays to an IBS ${}^4He^{++}$ through lattice interaction. Subsequent transitions between ion band states are allowed except at surfaces, where $^4$He is created, as observed[2]. The reactions, reactants, and products are volume distributed. The MeV energy release per reaction is distributed throughout the lattice. In each reaction only a small energy release occurs locally[4]. In $PdD_x$ IBS occupation requires high loading with $x \sim 1$.

## 7. Reactions

The allowed reactions are those that preserve spatial and bosonic symmetry, e.g.

$$2\text{-}D^+_{band} \rightarrow {}^4He^{++}_{band} \quad . \qquad (2)$$

$$3\text{-}D^+_{band} \rightarrow {}^4He^{++}_{band} + {}^2D^+_{band} \quad . \qquad (3)$$

$$4\text{-}D^+_{band} \rightarrow 2\ {}^4He^{++}_{band} \qquad (4)$$

$$2\text{-}D^+_{band} + {}^1H^+_{band} \rightarrow {}^3H^+_{band} + H\uparrow H\downarrow{}^{++}_{band} \quad . \qquad (5)$$

Reaction 2 is the primary cold fusion reaction. In Reaction 5 the spin-paired proton $H\uparrow H\downarrow^{++}$ acts as a boson on the length scale of the lattice interaction. Reaction 5 is proposed as the main source of tritium build-up.

There are a number of forbidden reactions which break spatial symmetry, but possibly occur during disruptive events that cause loss of periodic order. These reactions, which produce energetic particles, may be able to take place at surfaces, crystal boundaries, impurity sites, or dislocations, i.e. structures that disrupt periodic order.

## 8. References


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