Abstract

This work proposes the theory of "Deutonons", bosonic quasiparticles emerging from the collective dynamics of deuterium nuclei ($S = 1$) within a metallic lattice (palladium). Unlike fermionic systems, deuterons in palladium can evolve toward a macroscopic **Bose-Einstein Condensation (BEC)** state.

The spin-1 Hamiltonian is analyzed, demonstrating how the exchange interaction favors the singlet configuration ($S = 0$), maximizing spatial symmetry and the probability of nuclear tunneling. Deuterons represent the vibration quanta of this condensate, acting as energy carriers that allow the overcoming of the Coulomb barrier and decay toward the ^{4}He nucleus via non-radiative channels.

The "Deutonon" Condensate: Quantum Coherence and Cold Fusion in Palladium

Marcello Colozzo

"Charging" Palladium: A phenomenological approach to orbital degrees of freedom

Lattice defects and its electronic structure ($4d^{10}$) make palladium electrochemically interesting, due to its extraordinary hydrogen/deuterium solubility.

By "loading" palladium with deuterium, the individual deuterons (deuterium nuclei) arrange themselves in the lattice sites, and if the thermal energy k_BT is sufficient, electrons "add" to the conduction electron system, according to Fermi-Dirac statistics. As the deuterium concentration increases, the distance between the deuterons decreases, favoring a deuteron-deuteron interaction. In the system of the center of mass and the relative coordinate $\mathbf{r}$, the deuteron-deuteron interaction Hamiltonian takes the form:

$$H = H_{orb} + H_{spin} = \underbrace{-\frac{\hbar^2}{2\mu}\boldsymbol{\nabla}^2 + V_{scr}(\mathbf{r}) + V_{conf}(\mathbf{R})}_{H_{orb}} + H_{spin} \tag{1}$$

where μ is the reduced mass and $\mathbf{R}$ is the position vector of the center of mass. The term $V_{scr}(\mathbf{r})$ is the screened potential, i.e. the Coulomb repulsion screened by the conduction electrons which, as previously stated, have a higher concentration than that of the uncharged palladium. We assume that $V_{scr}(\mathbf{r})$ is a Yukawa potential:

$$V_{scr}(\mathbf{r}) = \frac{e^2}{r}e^{-k_s r} \tag{2}$$

Here k_s is the screening wave vector. In the presence of a strong screening component, we expect high values of k_s, and thus a "thinner" potential barrier. This would increase the probability of tunneling. The individual deuterons are bound to their respective lattice sites corresponding to the lattice defects of palladium. Due to thermal agitation, they undergo small oscillations around the equilibrium positions. This is phenomenologically represented by a three-dimensional harmonic oscillator potential:

$$V_{conf}(\mathbf{R}) = \frac{1}{2}\, M_d\omega_0^2\mathbf{R}^2, \quad \begin{cases} M_dc^2 = 938.2592\,\text{MeV} \\ m_pc^2 = 938.2592\,\text{MeV} \\ m_nc^2 = 939.5527\,\text{MeV} \end{cases} \tag{3}$$

Spin

H_{spin} can be explained along the lines of Heisenberg's model of ferromagnetism:

$$H_{spin} = J\,(r)\,\mathbf{S}_1 \cdot \mathbf{S}_2 \tag{4}$$

where $J\,(r)$ is the "exchange integral", while $\mathbf{S}_1, \mathbf{S}_2$ sare the spins of single deuterons. As is known, the latter has spin 1; therefore H_{spin} describes the interaction between two spin-1 bosons. From the rules of angular momentum composition, three possible total spin states follow: $S = 0, 1, 2$. The energetically favored total spin state is the singlet ($S = 0$) and allows the two nuclei to approach each other (remember that for bosons the total wavefunction, spin+orbit, must be symmetric with respect to particle exchange). For $S = 0$, the orbital wavefunction is symmetric, and allows maximum overlap of the single-nucleus wavefunctions, favoring the tunneling process.

In (4) the transition from the representation $(\mathbf{S}_1^2, \mathbf{S}_2^2, S_{1z}, S_{2z})$ to the total spin representation $(\mathbf{S}_1^2, \mathbf{S}_2^2, S_z, M_S)$ by reconstructing the spin singlet is determined by an exchange integral $J\,(r) > 0$,unlike ferromagnetism which requires parallel spins. More precisely, in ultracharged Pd, phonon-mediated interactions determine $J\,(r) < 0$, fforcing pairs of deuterons into a spin singlet state.

"Enriched" palladium has a higher resistivity due to the increased concentration of nuclei (and therefore, a higher frequency of electron-lattice collisions). However, the corresponding "distortion" of the lattice determines an effective attractive force (via phonons) that counteracts the Coulomb repulsion between the individual deuterons.

Nuclear Reactions to Helium-4 (^{4}He)

Given the above, the deuteron system constitutes an ideal Bose gas and, as such, exhibits the phenomenon of Bose-Einstein condensation for $T < T_c$, where T_c is the critical temperature of the system.

In the quantum coherence regime guaranteed by Bose-Einstein condensation, the fusion process within the lattice does not follow the "standard" energy channels (which would produce an excess of neutrons or tritium), but rather channels itself toward a clean thermal signature, specifically through nuclear fusion (a "silent" or heat-producing channel).

Unlike hot plasma, here the energy is not released via a high-energy gamma (γ) photon, but is transferred directly to the lattice phonons (thermal dissipation).

$$D + D \longrightarrow^4 \text{He} + 23.8\,\text{MeV} \;\; \text{(transferred to the grid)}$$

Although suppressed by the deuteron statistics, they can occur to a minimal extent:

$$D + D \longrightarrow T(1.01\,\text{MeV}) + p(3.02\,\text{MeV})$$
$$D + D \longrightarrow^3 \text{He}(0.82\,\text{MeV}) + n(2.45\,\text{MeV})$$

Conclusion

The dominance of the ^{4}He channel without significant neutron emission is a consequence of quantum coherence in the metal. In suggestive but effective language, it is the victory of Bose-Einstein statistics over electrostatic repulsion.