Solid State Boson Condensation Model of Cold Fusion

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ABSTRACT

This theoretical study is based on the second suggestion of Leaf Turner which was independently developed by Chubb and Chubb. It lead to the selection rule, Bosons In, Bosons Out, which helps to explain the low yield of tritons, protons, neutrons and ^{3}He. The production of the boson ^{4}He has now been correlated with simultaneous production of excess heat.

1. Introduction

There is growing evidence which will not be cited here that the formation of ^{4}He is intimately connected with excess heat production in the Cold Fusion experiments. More rigorous standards are now being imposed by investigators in contrast to the euphoric days of March 1989 when poorly characterized palladium samples were immersed in poorly prepared strong alkaline solutions. There is little evidence that the charged particles tritons, protons, neutrons or ^{3}He are the primary products of the reaction. They are fermions. This will become more understandable when the Solid State Paradigm of Chubb and Chubb is applied in place of the commonly used Free Space model.

Leaf Turner[14] at Los Alamos made two suggestions to account for the phenomenon, namely either Transmission Resonance or Boson Condensation. The former is the basis of the Bush-Eagleton[3,4] model. The latter has gone largely ignored. Barry Kunz[10] suggested that there should be a connection between superconductivity and "cold fusion". That is, Cooper pairs of deuterons could approach each

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other, that the relatively higher mass of the deuterons should significantly reduce the correlation distance, and that the reaction should occur in the vicinity of the Debye temperature of palladium or palladium hydride. He gave no further details. Later he noted that while d-d and d-t fusion does occur in high temperature plasmas and gasses, (where frequent collisions occur) other nuclear reactions such as pair-production and/or electron-positron annihilation require the mediation of a solid in almost all cases.

It noted here that superconductivity involves a boson liquid of electronic Cooper pairs which do not interact with the solid state lattice. Bogoliubov's theory of superconductivity[2] specifically includes the electrostatic interaction between bosons in Einstein-Bose condensation in contrast to the BCS theory. This lead the author to see a connection to superfluidity.

2. Paraphrase of Chubb and Chubb

To achieve some brevity, only a paraphrase of theoretical development by Chubb and Chubb[6] will be given here. They have a more detailed paper at this conference to which the reader is referred[7]. A very important ingredient of their theory and the present extension to temperatures above 0° K is the condensation of bosons into a Bloch state of deuterons and the use of a multi-boson wavefunction formulated in a Wannier representation. They call this a Boson-Bloch-Condensate phase or **BBC.** Born-Oppenheimer separability is another feature. The time evolution of this BBC state leads to the significant selection rule - **bosons in, bosons out,** since the short range nuclear wave-functions are constrained to be independent of the electrostatic (atomic) wave-function **only** during an intermediate time stage when the nuclear portions are constructed of neutron-proton-pair bosonic function Ψ_{np}.

Chubb and Chubb point out that the deuteron charges will be screened and bound by a "sea" of electrons i.e., all regions will be electrically neutral on the macroscopic scale, just as the electrons in a semiconductor are bound by the ion cores. We envision the BBC extending throughout the lattice and interacting only slightly with it. They say, "Just because a deuteron looks and acts like a particle in one situation..." it need not do so in another situation and similarly "...just because the energy is [usually] released entirely in one place .." does not constrain the release to be highly localized in another. Because of the wave nature of matter in a condensed phase the wave-function is spread throughout the material, only a small portion of any atom is located with any unit cell and only a portion of any nuclear reaction may occur at all periodically equivalent locations.

Note that all the particles are initially bound and the particles resulting from the nuclear reaction remain bound. The kinetic and potential energy portions of the Hamiltonian effectively cancel each out so that the right hand side of the Schrōdinger equation remains finite. Because of the nature of the wave function the worrisome "cusp" condition is avoided.

The s- and d- bands of PdD_x must be filled so that the Fermi Level lies very close to the maximum energy of the s- band. Hence x must be $(1-\delta)$: then thermally excited deuterons will occupy "ionic band states." Hence the PdD_x must be thoroughly charged electrolytically and this is a difficult feat since the deuterium diffusion rate in the deuteride falls dramatically when x exceeds about 0.7.

3. Boson Condensation

It is proposed herein that two superfluid rotons (involving deuterons) interact with an interstitial deuterium atom to yield the compound nucleus ^6Li which readily decays to $^4He^{+}*$ plus an excited $D^{+}*$ ion and the resulting energy can be dissipated readily in lattice by well known processes. This differs in small details from the suggestion of Becker[1]. Recently Nieminen[12] pointed out that even on the surface of a metal, hydrogen atoms are delocalized into surface band states.

The energy states of a system of identical bosons interacting weakly by pair-wise forces can be represented by the Hamiltonian

$$\underline{\underline{H}} = \sum{}'_{\mu} \; \underline{E}_{\mu} \langle B_{\mu}^{\dagger} | B_{\mu} \rangle + \underline{\underline{H}}' \qquad (1)$$

where the $\underline{\underline{H}}'$ is a small correction. The double underline has been used here to indicate an operator, and the $|B_{\mu}\rangle$ and $\langle B_{\mu}^{\dagger}|$ are Bogoliubov's canonically adapted annihilation and creation operators. The prime on the summation indicates that it does not include the value $\underline{\mathbf{k}} = 0$. The system energy is $\underline{E}_{\mu}$. The interaction corresponds to the disappearance of particles with momenta $\underline{\mathbf{k}_1\downarrow}$ and $\underline{\mathbf{k}_2\uparrow}$ (expressed in units of $\hbar$) and the appearance of particles in states with $\underline{\mathbf{k}_1\downarrow}$ and $\underline{\mathbf{k}_2\uparrow}$. The ground state of such a system of non-interacting bosons corresponds to condensation. The Cooper pair involves the further condition that $E(\underline{\mathbf{k}}) = E(-\underline{\mathbf{k}})$ and the momenta $\rho(\underline{\mathbf{k}}) = \rho(-\underline{\mathbf{k}})$ i.e., they are diametrically opposed quantities just outside the Fermi Surface. There is an energy gap and if the electric field is weak, any single particle scattering process - breaking up of the pair - is connected with an increase in the energy of the system of deuterons. The elementary excitations of a system of bosons between which weak repulsive forces are acting leads to the curve discussed below by Feynman.

The important boson fluid of excitations lies slightly above the Fermi Level and does apparently interacts with the lattice. These D^{+*} are cospatial with the other deuterons in a lattice unit cell.

Feynman[8] notes that the curve connecting the excitation energies as a function of the momentum ρ of the particles in a superfluid has one minimum. States linearly dependent on ρ are called phonons and those with momenta above the minimum ρ_0 are called rotons. The contribution of the phonons to the liquid goes as T^4 and only dominates over rotons at very low temperatures. Feynman sketched a periodic array of rotons in his figure 8. Rotons are created in pairs and attract each other. The correlation distance r in a non-ideal Bose gas is $r \approx \hbar/mu$. Note that the effective mass in the denominator is at least as large at that of the deuteron which in turn is roughly 3500 times the electronic mass. Note that the experimental correlation distance in two high temperature superconductors is given as 10 Å in ref.(5) and 3 Å ref.(11) resp. This would lead, because of the mass effect, to a correlation distance of less than 100 Fermis. There is a further effect.

In the case of electrons, spin information and exchange forces are conveyed by virtual phonons. In the case of nuclear forces, interparticle information is conveyed by means of virtual pions, which are bosons. Kenny[9] points out that binding by spin 0 bosons arises from Yukawa mass correction and the range of these is about seven times that of the usual nuclear components. Such long range forces have the ability to bring about coalescence of two or more deuterons.

The friction is essentially zero when a negative ion (such as D^-* which occurs in typical metallic hydrides) is accelerated by an electric field through the superfluid, up to a critical velocity and above this velocity (for roton emission), the number of states into which a roton can be excited grows rapidly.

While the superfluid phenomena in liquid helium occur below 5° K, the superfluid in superconductivity operates at or above the boiling point of liquid nitrogen. The proposal of a third kind of boson state, namely a superfluid of excited deuteron states as in BBC occurring at 300° K does not seem extraordinary.

4. Concluding Remarks

An extension of the ideas involves mild electrostatic interactions between the bosons which can lead to the BBC and the development of excited ionic band states which lie above the Fermi Level in PdD_{1-x}. The extension involves teachings from two other boson condensates, namely superconductivity and superfluidity. It is proposed that the interaction between a "stationary" interstitial D atom and two rotons rather than phonons give rise to bound reaction particles with a D^- carrying away part of the reaction energy.

Note added in proof.

In 1990, Rabinowitz[13] called attention to a possible connection between "cold fusion" and superconductivity, noting that Pd-D_x is a BCS superconductor, but apparently did not pursue this idea. He also discusses the fact that as a superconductor it exhibits a negative isotope effect. He discusses low-dimensional superconductors which may be pertinent to the Bush-Eagleton model.

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6. References

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