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Is a Quantum-of-Mass Always a Particle?

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ABSTRACT

It is argued that an understanding of condensed matter nuclear fusion and associated quantum physics has been made difficult by a historical failure to ask the right questions. Quantum physics begins with Planck's discovery that matter-energy is quantized, which introduces the concept of "quantum-of-mass". On a working level, the idea that a quantum-of-mass can best be viewed as a particle, like the popular picture of an electron, dominates popular culture. The paper shows the reader how, by returning to quantum-of-mass teaching, the possibility of a radiationless nuclear reaction converting deuterium into helium becomes understandable.

Questions

Sometimes confusion exists as a result of asking the wrong question. It seems to have happened in 1989, when Fleischmann and Pons (F-P) first published results on radiationless cold fusion. The question asked was: "where are the neutrons and protons which have been observed in all previously explored fusion processes?" This seemed a reasonable question to ask based on the physics of plasma fusion. However, in hindsight, this was the wrong question to ask for a process mediated by condensed matter. But this may not have been the most serious mistake made by physicists relevant to cold fusion.

Early quantum mechanics

A more serious wrong question may have been asked in the early 1900's when physicists and chemists asked "where are the electrons in an atom or a molecule?" Implicit in this question is another: "When viewed on the Angstrom scale of atoms, is a quantum-of-mass always a particle?" Planck's work showed that energy occurring in light and heat came in chunks, despite the wave pattern aspect of light that was demonstrated by its diffraction properties. These separate chunks are the quanta-of-energy called photons. Later experiments with slow moving mono-energetic electrons showed that electrons have similar wavelike properties. Their trajectories produced interference patterns similar to those shown by the quanta-of-light. The wavelengths of these slow moving electrons were named after deBroglie, who suggested their existence. However, the thinking of electrons as point particles was so well established that the possibility of electrons ever having a different shape was disregarded. The wave function $\Psi(x,y,z)$ describing an electron's charge distribution in an atom, or more precisely, the square of the magnitude of the wave function $|\Psi|^2$, became interpreted as a probability distribution for a point particle.[1] This widely popularized probability-function picture of a wave function is called the Bohr/Born interpretation[2]. It has played a major role in the World's failure to understand the possibility of radiationless cold fusion power.

The roots of the theory of light lay in Maxwell's formulation of the laws of electromagnetism. These laws showed the possibility of electromagnetic waves moving at the speed c, which is the emu/esu ratio between the cgs (centimeter, gram, second) units of charge.[3] Experiment showed that the constant c of electromagnetism had the same value and dimension as the measured speed of light. It was clear that light was an electromagnetic wave characterized by wave length λ and frequency ν, with $\lambda\nu = c$, the speed of light. Each color had a different wavelength. The roots of quantum mechanics lay in Planck's discovery that the known black-body radiation curve of energy vs. wavelength for light emitted from a hot solid was consistent with electromagnetic theory only if light energy was quantized, i.e. if the quantum-of-energy of light of a given color was a constant h times the frequency of the light wave. The constant in $E = h\nu$ became known as Planck's constant.

The point electron

The theory of atomic structure took form after discoveries by J. J. Thomson and Rutherford. Thomson discovered that the negatively charged particles liberated in gas discharges, i.e., the electrons, behaved in beam experiments in accord with the laws of classical mechanics as applied to particles of mass m_e and electron charge e. Rutherford showed that the compensating positive charge in an atom was located in a small volume at the center of the atom. It became natural to think of an atom as a planetary system with a heavy positive nucleus at the center and electrons moving in "planetary" orbits around the center. Bohr modeled the electron orbits of the hydrogen atom. He assumed that each allowed orbit was circular and had an angular momentum restricted to a value $Nh/2\pi$, with N a whole number. He calculated the energy of the atom for the electron in each of these allowed orbits, and showed that the differences between energies for different pairs of allowed orbits precisely matched the Planck energies of some of the spectral lines observed in spark discharges in hydrogen containing gas.

Electron delocalization

The electron-in-orbit picture is commonly presented to the public, and underlies the thinking of many persons as regards the atom. It is a point-electron picture. However, as Bohr knew, it violates the rules of electromagnetism. Maxwell's equations clearly show that a point charge subject to acceleration must lose energy to radiation. A particle in circular orbit around a central mass is constantly being accelerated towards the orbit's center. Its velocity continually changes direction, which means acceleration. It must continually radiate away some of its energy, which makes it spiral inwards toward the nucleus. So Bohr's stable orbits are unphysical. For atomic physicists, this difficulty was legislated away by introducing orbital stability as an axiom of the new quantum physics. This combination of point electron and orbital stability as applied to wave functions led to the interpretation of $|\Psi|^2$ as a probability density function, measuring the relative probability for finding a point electron in each small volume dxdydz. However, $|\Psi|^2$ is better interpreted as a measure of mass and charge density. If the charge density picture is used, there is no conflict between Bohr orbits and classical electromagnetism, because the electron's charge is smeared out along the orbit. The charge density does not change along Bohr's circular orbit, and the electron's "motion" is treated as a ring of constant current. There is no time-varying increase and fall-off of charge density at points around the ring. The acceleration-of-a-point-charge does not apply. The constant magnetic field associated with a time-independent current ring does not radiate away any of its energy.

Point electron models

Admittedly, there are many situations where the Bohr/Born interpretation of $|\Psi|^2$ as a point-particle probability density function gives the right answer. For example, when a gamma ray Compton-scatters off an atom, the interaction seems to occur at a single point "where the electron is located". The scattering produces a recoiling point-particle electron and a reduced energy gamma ray. However, this answer is also compatible with the charge density interpretation. When a gamma ray Compton-scatters off a cloud of charge density associated with smeared-out electrons centered on a nucleus, i.e., the electron matter in the atom, the most probable point of interaction will be where the electron charge density has its maximum. The smeared cloud of electron charge loses an electron quantum-of-mass, which is re-configured to form the scattered recoil electron. The scattering process causes the gamma ray to change direction and lose energy. If a gamma ray is going to interact with the electron cloud somewhere, common sense says it is most likely to do so where the cloud is most dense. A smeared cloud picture expresses Heisenberg's uncertainty principle, which is a fundamental aspect of quantum mechanics.

Consider another case where the quantum-of-electron matter can be approximately modeled as a mathematical point particle. In the classical television picture tube, beams made up of point-geometry electrons are sequentially directed by changing electric fields toward separate spots made up of different color phosphors. These spots make up the picture that we see.

Electron coherent partitioning

The situation is different, however, when one tries to explain the flow of electron charge down a metal wire. A flow of point-charges doesn't fit the observations. For a given current flow it takes too much electric field along the wire to keep a cloud of point electrons moving in a common direction. The volume of the wire is filled with bulky metal ions. Each bulky metal ion scatters any point electron directed towards its obstructing bulk. To avoid this scattering problem, it is necessary to model all the electrons involved in current flow as if they were members of a low density distribution of charge and mass, acting like a fluid which permeates the metal. In response to an almost vanishingly weak electric field imposed along the wire, this electron "fluid" slides around the bulky metal ions to the extent needed to conserve electron charge and to serve as the source of exiting electrons at the "downstream" end of the wire. In this idealized metal picture there is no electron scattering, i.e., no resistance to current flow.

In its low density "fluid" configuration, each electron quantum-of-mass has a delocalized density distribution that resembles the amplitude distribution of a 3-dimensional standing wave. Each such electron quantum-of-mass is partitioned into many small pieces, with its separated fractions acting in concert as a single entity. The separated pieces can be said to be entangled, and the sum of pieces can be said to behave coherently, i.e., they move in "lock-step". My name for the configuration change leading to this electron geometry is "coherent partitioning". In metals, these useful current-carrying quanta-of-electron-matter are called "quasiparticles". Each quasiparticle has the same charge and mass as the point electrons of the TV picture tube. Thus, based on real world observations one concludes that the conduction electrons in a metal are most usefully visualized as a quantum mechanical system which is characterized by a quantum-of-mass that is very different from a point particle.

The fermi sea

So a reader may ask: If the normal flow of current down a wire requires such a strange picture of mass flow, what other strange aspects of matter does metal physics force us to accept? As described above, electrons in a metal, instead of being little points flying through space, are in the form of 3-dimensional standing waves. When there is no current flow, these quanta-of-mass are confined within a 3-dimensional enclosure. Each such electron quasiparticle has many mass and charge density maxima. However, a cloud of such "electrons" has another peculiarity. The electrons making up each quasipaticle are not the same electrons that entered the metal. They have undergone multiple exchange symmetry operations. They have effectively merged with many other electron quanta-of-mass having overlapping geometry, so as to form what is called a "fermi sea". The continuous many-body picture of a fluid is required if one is to explain many of the properties of electron matter in a metal.

The merging of multiple wavelike electrons creates a medium unlike any other encountered in the normal world. It is a medium which is kept electrically neutral by having an equal amount of positive charge embedded within it, in the form of point-like, distinguishable, positively charged metal ions. These relatively massive ions configure themselves inside the electron fermi sea so as to form a crystal array that minimizes the Gibbs free energy of the ion + electron system. The very mobile, relatively low density electron fermi sea adjusts to this energy-minimizing ion lattice configuration. The resulting continuous mix of negatively charged electron matter and discrete metal positive ions pull themselves together, which creates a combined system resembling a bowl of fruit gelatin.

Degrees of freedom

A jelly-like piece of bulk metal is subject to body vibrations. Its resonant vibration modes can be thermally excited, in which case the vibrations store heat energy. The storage of heat energy as vibrations of a bulk solid (as in an insulator) is described by the Debye theory of specific heat.[4] The stored energy is quantized. The chunks of vibration energy are called acoustic phonons. Multiple phonons can be stored in each vibration mode, with a resulting increase in its vibration amplitude. Since the energy is stored as body vibrations, there is a coordinated motion of the constituent atoms.

In metals, the Debye theory works less well. While the specific heat behavior fits the Debye theory quite well in some metals, in others the theory's key parameter, the Debye temperature, must be determined empirically[4]. As stated above, a metal is composed of metal ions embedded in neutralizing electron matter. Below the Debye temperature most of the heat energy is stored in the coordinated motion of the metal ions. This motion carries along the neutralizing electron matter. By metal ions we mean the metal atoms minus their valence electrons. Half the heat energy is stored as metal-ion kinetic energy; half is stored as potential energy, i.e., as elastic strain within the bulk metal. In well behaved metals at moderate temperatures there is little or no heat energy stored as excitations of individual electron quasiparticles.

The ions in a metal contribute 3 N_A degrees of freedom to the coupled ion-electron medium, where N_A is the total number of metal ions in the metal's bulk. At very low temperature only very small chunks of energy are available. Only the longest wavelength modes of vibration (corresponding to the lowest tones in a church bell) can be energized. At

T_K = 0 degrees Kelvin the specific heat starts off at zero kcal/mol/deg. K. As the temperature is raised, independent resonant modes of higher and higher frequency can be energized. In the low temperature regime above absolute zero, specific heat increases as T_K^3. This low temperature behavior contrasts with the behavior of an ideal gas, for which the specific heat is independent of temperature. The specific heat of the metal rises with increasing temperature, but flattens off once all 3 N_A independent vibration modes become thermally excitable. The temperature above which no new independent modes of vibration become available for thermal excitation is called the Debye temperature. Specific heat depends on the number of modes available to store additional energy. Above the Debye temperature the number of modes remains constant, but each of the 3 N_A independent vibration modes can add energy by storing multiple numbers of acoustic phonons. This behavior is expressed by the Dulong-Petit law for specific heats, which says that the molar specific heat of a solid should level off at three times the gas constant, i.e., at about 6 kcal/mol, regardless of lattice details. In an idealized metal at low and intermediate temperatures, none of the thermal energy is stored as excited electrons.

Zero-point motion characterizing bound atoms, molecules, and ions

Now consider the quantum physics of localized single "particles" trapped within a potential well inside a solid. Does quantum-of-mass delocalization physics apply to non-electron "particles", like atoms, protons, and deuterons? Quantum mechanics says it does, if the "particle" is confined within a potential well. Consider a non-partitioned system like a whole single atom. Just as a single electron bound to a hydrogen nucleus exists as a smeared-out distribution of electron-matter density, in the same way a bound single atom exists as a smeared out distribution of atom-matter density when confined inside a sub-nanometer pore inside a piece of bulk metal. The smearing-out of a bound "particle" is a delocalization quantum mechanical phenomenon. Delocalization applied to whole atoms, molecules, or ions trapped within a potential well provided by a larger system is said to be due to "zero point motion". If Hooke's-law forces hold an atom within such a potential well, the atom's ground state wave function is a 3-dimensional Gaussian. The Gaussian atom-density distribution is the Hooke's law equivalent of an atom's ground-state "electron orbital", where an electron is trapped within the potential well provided by the atom's nucleus.

Coherent partitioning of protons and deuterons

The Hooke's law trapped atom picture includes the case of a hydrogen atom adsorbed on the surface of a metal crystal. An adsorbed hydrogen atom is really an adsorbed hydrogen ion neutralized by electron charge borrowed from the electron's fermi sea, with the "ion+electron's" smeared volume confined to a potential well above the metal's surface. This neutralization of ion charge is called dressing.[5] Now consider the effect of metal crystal periodicity. Since the surface of a metal is periodic, it provides an array of candidate potential wells throughout which the adsorbed atom in principle could reside. This array of surface wells provides an environment within which the quantum-of-mass of an adsorbed atom might be able to change its geometric configuration from a zero-point-motion configuration to a coherently-partitioned lattice geometry. If partitioning occurs, the occupied segment of the metal surface becomes an "ion coherence volume". The change would be like what happens to electrons when an electron in a battery moves from an electrolyte into a metal anode. The question arises: Can an experimenter create conditions that stimulate coherent partitioning of hydrogen ions (deuteron or proton) initially confined to a metal surface?

Experiments say yes. Experiments have shown that both protons and deuterons adsorbed on a metal can be stimulated to change from a localized zero-point-motion configuration to a coherently partitioned form. Especially pertinent are observations by Puska et al. and Astaldi et al.[6]. These observations, combined with calculations, have shown that protons and deuterons on Ni and Cu, when hit by beamed electrons, are scattered into excited surface states having the same multi-maxima density form possessed by electrons in metals. The experiments showed that the scattered protons and deuterons gained energy that matched the predicted energy gain based on well-proven many-body theory. My name for these coherently-partitioned protons and deuterons is "Bloch ions", named after Felix Bloch. They have the same coherently-partitioned periodic symmetry as characterizes electrons in metals, which is called Bloch symmetry. Bloch ions are the occupants of postulated "Ion Band States",[7] and groups of such ions were originally called "boson Bloch condensates".[8]

Ion Band State Theory Plus

Let us now consider the Ion Band State Theory of cold fusion.[7] The theory postulates that F-P cold fusion requires deuterons in Bloch states. Does evidence support this requirement? Are such Bloch geometry versions of protons and deuterons present in all successful cold fusion experiments? In considering this question one notes that a Bloch standing wave can be either a surface wave or a volume wave. It can have either 2-dimensional symmetry or 3-dimensional symmetry. Furthermore, although deuteron waves fit the F-P fusion picture, the possibility of proton waves undergoing different exothermic nuclear reactions needs to be kept in mind. The balance of this paper considers only deuteron reactions.

Deuteron Bloch waves are modeled similarly to electron Bloch waves. In a metal each of the Bloch electron quasiparticles (electron quanta-of-mass) has a partitioned geometry wave function containing N_{well} discrete local maxima, with the density concentration present in each local maximum coherently coupled to all the others. The volume of crystal containing these N_{well} local maxima constitutes a deuteron coherence volume. The coherence expresses entanglement.

A metal crystal as a part of a piece of bulk metal is a lattice made up of a large number of repeating array elements called unit cells. An individual crystallite functioning as a deuteron coherence volume contains a lesser number of unit cells. Its extent is characterized by its number N_{cell} of unit cells. The number of potential wells N_{well} is typically 1, 2, or 3 times N_{cell}. A deuteron coherence volume is typically very much smaller than that an electron coherence volume. For example, a 100-micron crystal of bulk metal over which electrons might be coherent could maybe contain several million independent deuteron coherence volumes. The smaller size of the deuteron coherence volume is a likely result of the deuteron's shorter deBroglie wavelength. There seems to be a stricter periodicity requirement for onset of deuteron coherence, reflecting a need for greater crystal perfection and leading to smaller coherence domains.

Delocalization process

First consider electron delocalization. Start with a piece of metal and consider its conduction electrons. At some time in its past history the more loosely bound electrons in the metal were subject to Bloch delocalization. The metal's valence electrons converted themselves to a coherently partitioned geometry when the metal was first formed. Make a wire out of this metal and place it in a battery driven electric circuit. A change to Bloch geometry occurs when an electron moves from the battery's electrolyte into its metal anode. Reversing this step, electrons displaced from the metal change from Bloch geometry to a non-partitioned geometry when they flow from the battery's cathode into its electrolyte.

The Ion Band State Theory of cold fusion assumes that a fraction of the deuterons in a metal deuteride undergo a change in configuration within a candidate coherence volume at some time prior to cold fusion events. The change process is different in different cold fusion environments. In F-P type electrolysis the change occurs in or on a cold fusion cathode in a different environment than it does in Arata-Zhang work, which uses metal nano-crystals.[9] In the Iwamura et al. nuclear transmutation experiments the environment differs from either of the above. The first step in the Iwamura process is believed to be a coherent partitioning of 2 or more deuterons, followed by a F-P cold fusion event. The delocalization and subsequent fusion event are modeled as occurring within the interface volume between CaO ionic crystals and contacting Pd metal.[10] In this modeling a segment of the interface volume between ionic solid and metal becomes a 2-dimensional-symmetry deuteron coherence volume. The deuteron coherence volume functions as nuclear reaction domain. In the other condensed matter scenarios, different types of deuteron coherent volumes are involved.

Nuclear reaction domains

Quantum-of-mass thinking brings along with it a different way of looking at nuclear fusion reactions. Instead of thinking about a "point" reaction site, one thinks about a small crystallite volume of space which becomes a nuclear reaction domain. Modeling suggests that a typical reaction volume is of nanometer dimension. There are $\sim 10^{18}$ nanovolumes in a cc of metal, each of which could in principle host a collection of deuteron quanta-of-mass. Individual nanovolumes function as individual nuclear reaction domains where cold fusion reactions can take place. To get high cold fusion power density it is desirable to have a high density of such domains. This consideration leads to the teaching "Small Crystals Are Better". [11]

Metal vs. deuteron coherence volume

The physics of partitioned deuterons embedded in a neutralizing electron medium is different from that of an electron fermi sea neutralized by an array of metal ions. Electron fermi sea behavior is greatly affected by the fact that the atom and electron masses are very different, with $m_e << m_A$. This means that the DeBroglie wavelengths of electron are much greater than those of the ions. Equally important, quantum mechanics requires that electrons follow rules applicable to "indistinguishable" particles, whereas metal ions and interstitial deuterons in self-trapping sites must follow the rules of "distinguishable" particles. The Bloch deuterides of Ion Band State Theory must follow the rules of "indistinguishable" particles. Indistinguishable particles are subject to the wave function math requirement called "coordinate exchange symmetry".

Electrons, being fermions, take up physical space, as expressed by the Pauli exclusion principle. The electrostatic force between metal ions and the metal electrons pulls the mix together. A normal metal deuteride, which has interstitial deuterons in self-trapping sites[12], behaves like a metal. The long wavelengths of the electrons causes the electrons to be squeezed, which forces them to fully fill all accessible quantum states up to the metal's fermi energy, which is well above the energy of room temperature thermal quanta. The fermi sea has negligible mass density. It is in a sense present everywhere, and simply flows around and neutralizes (dresses) the embedded positive charges of the metal ions without effort or detectable delay.

A deuteron quantum-of-mass lattice

Consider a single Bloch deuteron, designated D^+_{Bloch}, in a Bloch deuteron coherence volume. The D^+_{Bloch} contains 2 "entities", a single deuteron and neutralizing electron charge. Both are quanta-of-matter configured like the host lattice within which, or on which, they are "embedded". It is helpful to think of D^+_{Bloch} as both a single deuteron and a single quantum-of-mass with lattice geometry. The lattice geometry adds new degrees-of-freedom to the deuteron's quantum-of-mass.[16] The extent of deuteron partitioning is determined by N_{well}, which determines the effective number of lattice-induced degrees-of-freedom that characterize the D^+_{Bloch} lattice. We refer to the added degrees of freedom as "lattice-induced degrees-of-freedom".

Fusion of lattice-geometry deuterons

Assume for the moment that F-P cold fusion creates Bloch ^4He, designated $^4He^{++}_{Bloch}$, from two D^+_{Bloch} deuterons. The fusion product $^4He^{++}_{Bloch}$ starts its life as part of the electron-neutralized Bloch deuteron pair which gave it birth. Once it is born, it becomes a distinct new Bloch ion, namely, a Bloch ^4He nucleus, neutralized by the same 2 neutralizing electrons. Note that the neutralizing electrons in the deuteron coherence volume have joint membership in the deuteron coherence volume and the bulk metal.

The same lattice geometry applies to both the feedstock deuterons and the nuclear product $^4He^{++}_{Bloch}$. When more than one Bloch deuteron is present in the same deuteron coherence volume, each deuteron is partitioned within the same potential wells. If N_{well} exceeds a critical number,[11] spin-zero deuteron partners are "merged" by the required imposition of coordinate exchange symmetry.[13,14] The paired ions, $2D^+_{Bloch}$, are superposed and not subject to any explicit Coulomb barrier. Superposition of spin-zero pairs brings the strong nuclear force into play. The strong force pulls on the superposed 2-deuteron configuration, reducing its size to nuclear dimension. The superposed spin-zero pairs have symmetric wave functions. In nuclear physics language the state symmetry designation is 0+.[15] The reaction is designated a $0+ \rightarrow 0+$ nuclear reaction. The transition is radiationless because energetic particle emission is prevented by the lattice geometry. The reaction becomes irreversible if any nuclear energy is transferred to the hosting metal.

Lattice-induced degrees-of-freedom facilitate energy transfer to the metal

Lattice-induced degrees of freedom are important in condensed matter nuclear physics.[16] Let us start this part of the discussion by returning to the non-partitioned ion picture of a deuteron trapped in a metal pore within a metal. The trapped deuteron has 3 degrees of freedom. As previously described, the 3 degrees of freedom describe the spatial distribution of atom density within the pore. Now consider the case of a diatomic D_2 molecule trapped within a pore in a metal. The molecule trapped in the same pore has 6 degrees of freedom, 3 from each deuteron. Three of these degrees of freedom describe the spatial distribution of molecule density within the pore. The other three describe the relative rotation and vibration motion of a rotating, vibrating dumb-bell shaped object, i.e., they model a diatomic molecule expressed in an "internal coordinate space". The Bloch double deuteron $2D^+_{Bloch}$ has a similar set of 6 degrees-of-freedom. But if it is in a deuteron coherence volume containing 1000 potential wells, it has an additional set of 3000 lattice-induced degrees of freedom, giving a total of 3006. Of these, 3 degrees-of-freedom describe the location of multiple density maxima with reference to the metal lattice; 3 describe its "internal structure", i.e., size, baryon pairing, and internal vibration-distorted shape of the $^4He^{++}$,[15] and 3000 are a result of the $^4He^{++}_{Bloch}$ quantum-of-mass lattice configuration. The cold fusion reaction is primarily an internal-structure collapse in size of a superposed 0+ deuteron pair.

Note that the initial double Bloch deuteron form is different from that of a coherently partitioned D_2 molecule form. The double Bloch deuteron is two superposed partitioned deuterons, i.e., $2D^+_{Bloch}$, whereas the coherently partitioned D_2 molecule is made from two side-by-side non-partitioned D-atoms, subsequently partitioned, i.e., $(D_2)_{Bloch}$. Only the superposed partitioned-deuteron configuration $2D^+_{Bloch}$ undergoes cold fusion. At sufficiently large N_{well},[11] the two deuterons in the $2D^+_{Bloch}$ configuration share the same potential wells, have no Coulomb potential barrier, and are superposed, hence overlap each other.[13,14] Radiationless dd fusion is no longer blocked.[13]

<u>De-activating the excited nucleus</u>

When 2 spin-zero Bloch deuterons are pulled together by the nuclear strong force, they fuse exothermically to create a double-deuteron type of Bloch ^4He nucleus. The nuclear reaction energy is available to excite both inside nucleus vibrations and any or all of the $^4He^{++}_{Bloch}$ lattice-induced degrees-of-freedom. The excitation quanta of the lattice-induced degrees-of-freedom are nuclear-lattice acoustic phonons. Most of these Bloch geometry ^4He acoustic phonon energies are large, but much less large than excitations of the inside-nucleus vibration modes associated with internal nuclear structure[15]. The lattice-induced nucleus degrees of freedom add sets of hyperfine energy levels to each of the internal-structure vibration excitation levels. The presence of hyperfine excitation states enormously increases the number of energy levels designating nuclear metastable states, as shown in the Figure. Though the nuclear acoustic phonon levels are more widely spaced than corresponding metal phonon levels of the metal crystal lattice to which the deuteron subsystem is bound, the lower-energy acoustic nucleus-phonon values match onto a subset of the higher-energy acoustic metal-phonon values. This energy matching creates a means of nucleus de-excitation that is not available in normal nuclear interactions.[16]

Li resonances vs. Fermi Golden Rule reactions

To understand the details of energy transfer from a newly fused Bloch nucleus to its surrounding metal environment, it is essential to treat the nucleus as a lattice geometry object. The lattice-induced degrees-of-freedom make possible a sequential flow of energy from the newly formed nucleus to the metal. This energy release mechanism is completely different from the all-at-one-time transfer of energy of classical nuclear physics. The Bloch nuclear reaction forbids the energetic proton and neutron emissions of the normal hot fusion reactions. Such emissions do not match onto the lattice geometry of the process.

When an excited Bloch nucleus has excess energy, its energy can cascade downward by sequential transfers of acoustic phonons (vibrations of the nuclear lattice) to the hosting metal. The cascading reactions are superposed deuteron versions of Li-Feshbach resonances. When perfect energy matching occurs, there is no transfer of energy. In the Li modeling[17], a perfect resonance is replaced by a slightly perturbed lossy resonance, consistent with a weak coupling of the nuclear system to the metal lattice. Li models the lossy resonances by adding a dissipative term to the nuclear interaction potential which expresses the strong force Hamiltonian. A non-perturbed isolated resonance fails to transfer any energy. However, even weakly perturbed resonances are lossy and involve transfer of a chunk of energy.[18] Lossy resonance theory describes acoustic phonon energy transfers between nucleus lattice and hosting metal fermi sea. Phonon energy transfers are steps in an energy transfer cascade. It may be beneficial to think of the transitioning Bloch system as in a mixed quantum state during the energy cascade.[19]

The superposed partitioned-deuteron of a Li resonance reaction competes with Fermi Golden Rule reaction steps. The reaction matrix elements are larger with Fermi Golden Rule modeling[7]. Major downward jumps in energy occur. Large quantized momentum transfer pulses characterize the Fermi Golden Rule process. However, both reaction rate theories likely play a role, and their relative contributions need to be explored. Momentum pulses might promote the subsequent energy transfers (Galilean transform stimulation[20]). It may be that momentum-pulse self-stimulation causes cold fusion energy release to flicker.

Conclusions

Although it is often taught that the wave function of quantum mechanics only has meaning as a probability distribution for locating a particle[2], Roger Penrose[21] and others argue that the wave function has a deeper meaning. In quantum-of-mass language the wave function describes a distribution of matter density, i.e., a matter density field. A metal crystal provides a periodic symmetry environment which can impose periodicity on suitably prepared H^+ and D^+ ions. The resulting quantum-of-mass has Bloch-symmetry. Bloch D^+ ions are coherently partitioned deuterons. They have separated charge-density maxima which are mutually entangled. Pairs of D^+_{Bloch} ions are subject to increasingly reduced dd repulsion as the extent of coherent partitioning is increased, leading to a no-Coulomb-barrier, superposed-deuteron wave function. Reactive Bloch deuteron pairs are characterized by spin-zero, spatially-symmetric 2-body symmetry (0+ symmetry). F-P fusion collapses the volume of the superposed deuterons. A coherently-partitioned quantum-of-mass 2-deuteron lattice stepwise transfers packets of nuclear-origin phonon energy to a hosting metal lattice during a 0+ → 0+ transition. The lattice geometry forbids energetic neutron and proton emission. The result is radiationless $2D^+_{Bloch}$ fusion to $^4He^{++}_{Bloch}$, accompanied by a slow 24 MeV release of heat within a hosting metal.

Comments and References:

1. This early quantum mechanics modeling is based on my reading of portions of F. K. Richtmyer and E. H. Kennard, "Introduction to Modern Physics" (McGraw -Hill, New York, 1942); Chapters I, II, and III of F. Seitz, "Modern Theory of Solids" (McGraw -Hill, New York, 1940); and Chapter I of L. I. Schiff, "Quantum Mechanics", Second Edition (McGraw -Hill, New York, 1955). More recent modeling of the effects of crystal structure are discussed in N. W. Ashcroft and N. D. Mermin, "Solid State Physics" (Holt, Rinehart and Winston, New York, 1976).

2. P. Atkins and R. Friedman, "Molecular Quantum Mechanics", 4th Edition, (Oxford University Press, Oxford, 2005), p. 23, discussing the **Born Interpretation** say: "The wave function itself is a **probability amplitude**, and has no physical meaning." T. Hey and P. Walters, "The Quantum Universe", (Cambridge University Press, Cambridge, 2005), p. 159. Discussing Max Born they write, ".. we should give acknowledgment to the physicist who first recognized that Schrodinger's wave must be interpreted as a probability wave. ...... he was awarded the Nobel Prize for his probability interpretation of the quantum mechanical wave function".

3. L. Page, "Introduction to Theoretical Physics", (Van Nostrand, New York, 1935). The speed of an EM wave through a medium with permeability μ and permittivity (= dielectric constant, p. 374) κ is $v = c /(\mu\ \kappa)^{1/2}$ where electromagnetism constant c is the charge ratio abcoulomb/statcoulomb (pp. 486-488). The abcoulomb is the cgs electromagnetic unit of charge. Charge measured in abcoulombs times particle velocity measures the contribution of a moving charge to

electromagnetic current as measured in abamperes. Current in abamperes produces magnetic field intensity H as measured in gauss (≡ oersted). It measures magnetic flux density. Lab measurements show that the abcoulomb/statcoulomb ratio closely matches the known value of the speed of light. In Heavyside-Lorenz units μ and $\kappa = 1$.

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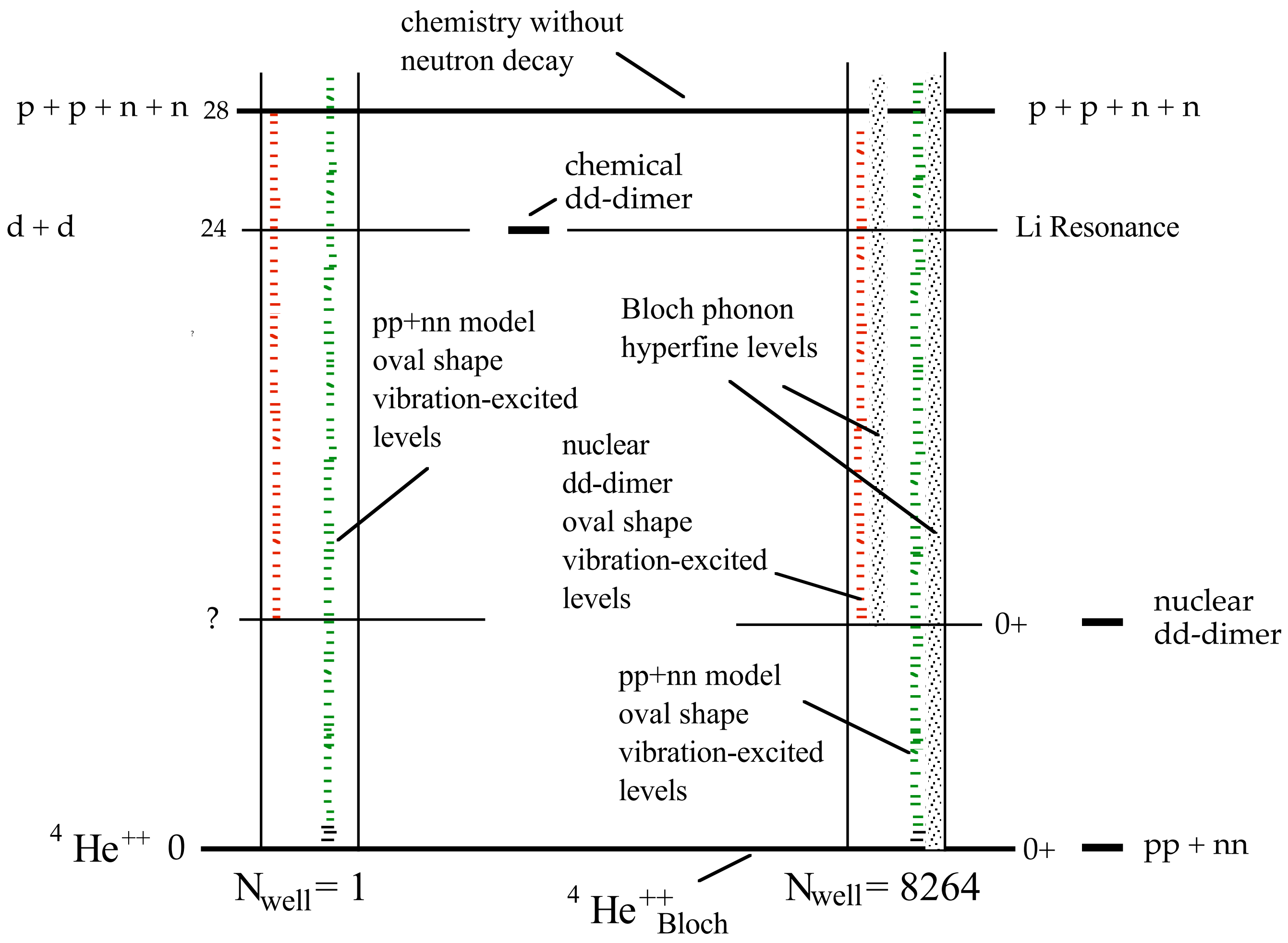
reasonable to me."   -   " I would argue that ψ is clearly much more than a probability wave."

Figure Caption

The Figure is a chart showing envisioned energy levels of a coherently partitioned ^{4}He nucleus. For details, see *Proc. ICCF11* (Ref. 3, p. 692). The nucleus is envisioned as having 2 metastable forms: Form 1 based on the strong force interaction between deuteron pairs; Form 2 based on interaction between a zero-spin neutron pair and zero-spin proton pair. Each form of coherently partitioned ^{4}He nucleus is assumed to have its own coarse spectrum of internal-structure nuclear vibration states. Each Bloch-configuration deuteron has the geometry of a lattice, and has more than 3000 independent lattice-induced degrees of freedom. These lattice degrees of freedom split each internal-structure vibration level of Form 1 or 2 into 3000 or more hyperfine levels. Excitations of the hyperfine levels are nuclear-lattice acoustic phonons. - Fusion reactions with lossy Li resonances have anomalously high reaction rate, but reduce the energy of an excited nucleus only slightly. Alternative non-resonant reactions in accord with the Fermi Golden Rule use Mossbauer-type momentum transfers to deliver larger chunks of momentum and energy to the metal host. A reaction cascade is envisioned as transferring the full fusion energy to the hosting metal.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