Cold Fusion Energy Research Co. - Theory

An Interdisciplinary Science

The biggest obstacle thwarting the development of cold fusion as a clean energy for the future is THEORY, not EXPERIMENTS. It is a hesitation of the engineering and science communities to recognize that the quantum physics of metals can be applied to the reaction physics of nuclear science. The nuclear engineering and science communities know that cold neutrons can flow into selected uranium nuclei, energizing the nucleus in a manner that releases some 230 MeV of nuclear energy. But they see no way by which a positively charged deuteron can enter a nucleus at room or boiling water temperature. This is a problem since for cold fusion to occur, two deuterons must join each other to create a helium nucleus and release heat. Ironically, the theory disconnect is mainly due to the same specialization that has led to the rapid technology advance that has made present day society possible.

The technology that explains cold fusion is multiply interdisciplinary. Cold fusion seems most easily explained using the languages of chemistry and metal physics, but it also requires inputs from nuclear physics and other specialties. Chemistry builds on atom and molecular physics, while the physics of metals is part of material science and has a parallel in the astrophysics of white dwarf stars. All of these are part of quantum science and subject to its disputed interpretations and its mathematical languages.

Despite all these apparent complications, cold fusion is not more difficult to understand than many of the specialties that make modern life possible. We all understand the law of conservation of energy, and that one can convert stored chemical energy into heat by burning fossil fuels. There are additional rules similar to conservation of energy that apply to the submicroscopic world of quantum mechanics. Once these theory requirements are recognized, most of cold fusion science can be understood.

Listening to Chemistry

The mystery of cold fusion is based on the mystery of chemistry. Ever since Rutherford showed that the negative and positive charges that make up an atom have a structure in which most of the positive charge is located in a hard nucleus at the center of the atom, there has been the mystery as to what keeps the negatively charged electron matter from falling into and combining with the positive nucleus at its center. After all, the pull of the positively charged nucleus at the center of the electron "cloud" is vastly stronger than the pull of gravitation. Maxwell's theory of electromagnetism says that a moving localized electron charge must continuously lose energy if it is confined within a closed volume like that of an atom. Something else must be going on.

There are two things going on. It turns out that an electron requires more volume to "live in" when its kinetic energy is low than when it's kinetic energy is high. Also, when it occupies this volume, there is no room for another electron with the same low energy to be in that same volume. The first of these rules is the so-called Heisenberg uncertainty principle, and the second is Pauli's exclusion principle. Without these two governing principles there would be no atoms, no molecules, and none of us humans trying to figure out the rules. With these rules operating, electrons crowd in as tightly as possible around the positively charge nucleus. Some people think of an atom as mostly empty space, which is true from the point of view of a radioactive decay particle like the alpha particles used by Rutherford in his famous scattering experiments. But if one views things from the electron's point of view, the atom is fully packed with electron matter crowded around the nucleus as tightly as possible.

Chemistry describes the many ways in which electrons can organize themselves to get close to the nucleus. In general, electrons seek to organize themselves so as to create the lowest possible

energy arrangement. In molecules, there are multiple nuclei, and when there are more than 2 atoms, there are multiple geometric arrangements that can be formed. The atomic nuclei seek locations such that their combined system of "point-like" nuclei and space-occupying electrons are in the lowest energy configuration. Some geometric arrangements of the atoms can lead to a lower energy than other arrangements of the same atoms. Both are valid molecules, but only one has the lowest energy and is therefore the most stable. The other configurations can be almost as stable and equally useful as long as the geometric changes required to get to a lower energy shape are blocked by a high enough energy barrier.

Returning to atoms, the organized volumes that electrons fill in their attempt to minimize energy for the various atoms of the Periodic Table are called atomic orbitals. Each of these orbitals has its own shape and electron matter density distribution.* These orbitals have names. Figure 1.2,1 on page 9 shows the shape and density distribution of an *s*-orbital. The electron density distribution is spherical and describes the hydrogen atom. As one moves across the Periodic Table to atoms containing more electrons, the orbital shapes assume surprising form. Once you get to atoms having 5 or more electrons, you encounter the *p*orbital. Figure 3.3,1 shows the density distribution of a *p*-orbital, such as describes the outermost electron of the boron atom.

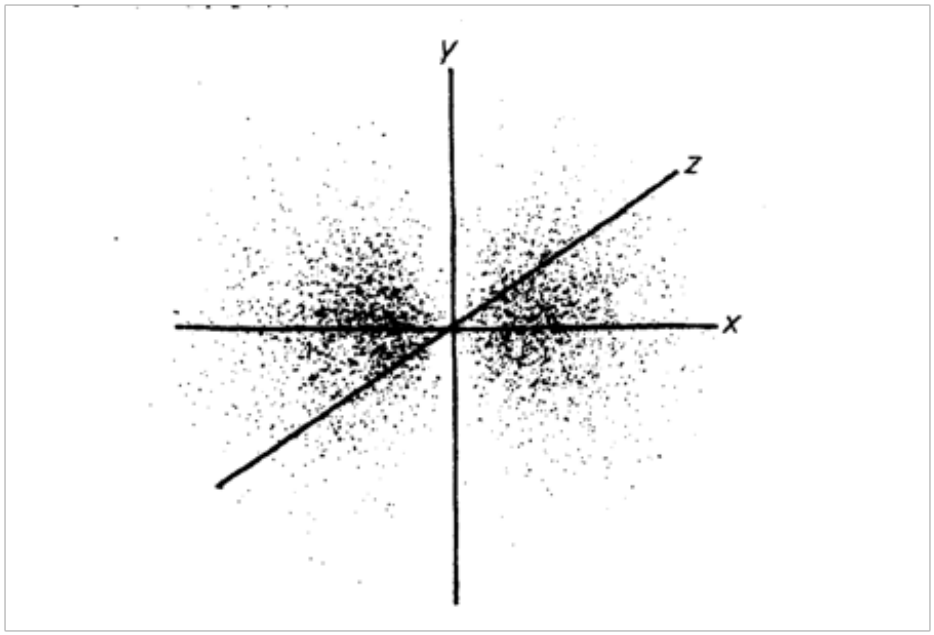

Fig. 3.3,1 The *p*-orbital of the outermost electron of the boron atom. The orbital is occupied by a single electron. The orbital is best pictured as a distribution of electron density which is partitioned into two halves, and which is continuously and smoothly present throughout the dotted volume. The electron matter is "coherently partitioned", yet behaves as a single entity, which is to say that the separated pieces are "entangled". The sum of pieces is the electron. The electron is best thought of as a quantum-of-mass of electron matter.

* The textbook used by American University is "Chemistry, The Central Science" by Brown, LeMay, and Bursten. It describes orbitals as **probability density** or **electron density** distributions (pp. 231-232). Electron density fits Penrose's "The Road to Reality", as discussed in Chapter 3.8.

The electron density distribution of the boron *p*-orbital illustrates a key aspect of submicrosopic physics. The *p*orbital of the boron atom is occupied by a single electron. The electron density of the single electron is split equally between the two lobes despite the fact that the electron density at the node between the two lobes is zero. Each lobe

is occupied by half of a single electron. The electron density of the single electron is split equally between the two lobes despite the fact that the

rules of classical physics says this partitioning cannot happen. Each lobe

contains half of the electron's matter. The electron is coherently partitioned into two halves. The two halves of the *p*orbital are "entangled". This situation exists because the split electron shape minimizes system energy. Mathematically, one must sum over the two density distributions to get what we call an electron. Energy minimization, coherent partitioning, and entanglement are

distinguishing features in the physics of cold fusion.

The same split-density distribution situation applies to the carbon atom, which has two *p*orbitals, each occupied by a single electron, and nitrogen has three *p*-orbitals, each occupied by a single electron. In nitrogen the three *p*-orbitals are oriented along the x, y , and z directions of space (e.g., up-down, north-south, and east-west.).

Chemistry is mostly the chemistry of isolated molecules. The nuclei in the centers of atoms forming molecules can be arranged in an enormous variety of geometric configurations. Some arrangements are very simple, like the straight line geometry of the carbon dioxide molecule CO2. Some are in the form of a "ring", like the carbon atoms in the benzene molecule. Some are like the pulled wishbone of a chicken The water molecule H2O has this angular form. The 2 legs of the wishbone form an angle of 105 degrees. In each molecule there are some electrons that are shared between 2 or more atoms. These shared electrons are called bonding electrons, or bonds. The bonding electrons are really orbitals, and have their own distinctive density distributions. The bond types and their geometries are an important part of modern chemistry. Their shapes and volumes can be visualized just like the electron matter orbitals of atoms. The bonding volume is densely packed with electron matter, and can be pictured in the same manner as atom orbitals.

Listening to Metal Physics

The physics of metals is an extension of the chemistry of molecules as applied to very large molecules with a periodic arrangement of metal atoms. Metals have a somewhat higher density than the typical molecule. The abnormally high density of metal crystals means an abnormally high electron density. The abnormally high electron density in combination with periodic array order creates a special type of chemical orbital consisting of a many interconnecting lobes in a lattice array. When an electron fills this orbital, it is called a quasiparticle. A grouping of array orbitals sharing the same array structure is called a band, and the electron occupants are called band state electrons. These band state electrons are the electron quasiparticles. They are the charge carriers that flow through the metal when a wire carries an electric current.

The huge abundance of electron quasiparticles is what makes a metal different from other crystalline solids. A solid having a much smaller number of the electron quasiparticles is called a semiconductor. Non-conducting solids like ionic crystals, covalent solids, and plastics have no quasiparticles. The enormous collection of quasiparticles in a metal is called a fermi sea, named after Nobel Laureate Enrico Fermi. The fermi sea electrons populate a near continuum of energy levels up to a maximum energy level called the fermi level. The electron fermi sea neutralizes embedded metal ions. The metal atoms became positive ions when they donated their outer electrons to the common pool, i.e., the fermi sea.

The number of interconnecting lobes in an electron quasiparticle orbital is enormous. Whereas a *p*-orbital consists of 2 lobes (potential wells) on opposite sides of an atom's nucleus, a metal quasiparticle orbital can consist of 1015communicating potential wells. This number is 100,000 times Earth's population. The Pauli exclusion principle that limits occupation of chemical orbitals to no more than 2 electrons per x,y,z state, also applies to quasiparticle orbitals. Pauli exclusion limits the electron density even at high pressure, preventing shrinkage that would otherwise occur. As in molecules, the relatively large volume required by the electrons in the solid is what determines the density of the solid. Among other things Pauli physics prevents the shrinkage of the Earth under the pull of its own gravity.

The type of orbital (chemical vs. quasiparticle) occupied by an electron depends on its environment. During battery operation, an electron belonging to an ion in a battery's electrolyte enters the battery's metal anode and converts from a chemical orbital form to an electron quasiparticle orbital form. It joins the electron fermi sea. Electron quasiparticles then flow through the wires of the electrical circuit, arrive at the battery's metal cathode, and convert back to molecular orbital form as they re-enter the electrolyte.

The job of the cold fusion reactor designer is to create a situation where deuterons initially in heavy water or deuterium gas enter a metal and convert to deuteron quasiparticle form. This conversion can be made to occur in small sub-volumes of a metal crystal, consisting of 10^3potential wells. This spread-out orbital form creates a very low density type of deuteron matter in which each deuteron's charge is coherently partitioned into many small fractional pieces. The quasiparticle deuterons have their own multi-lobe orbital structure, which means that they occupy their own set of communicating potential wells. When two suitably paired quasiparticle deuterons are occupying the same set of potential wells, there is a pairing of fractional charges present in each well, but the amount of opposing charge present is too small to keep the fractions apart. Coherent partitioning means that the fractional pieces are "entangled", which means that one must sum over all the pieces to see what really happens. Even after summing over all the pieces, the deuterons have made contact. Having made contact, the paired quasiparticles fuse in response to the nuclear strong force.

A quasiparticle fusion event can be pictured as taking place in 2 steps. Prior to the first step, all the quasiparticle deuterons in a given volume were paired with all the other quasiparticle deuterons in what is called a many-body system. They formed their own multi-lobe swimming pool. The resulting density distribution of deuteron positive charge was neutralized by negatively charged electron matter borrowed from the electron fermi sea. The number of electrons borrowed from the fermi sea equals the number of quasiparticle deuterons in their many-body system. This process of neutralization is called dressing. Dressing means that a portion of the electron fermi sea coexists in the deuteron's potential-well volumes and limits the range of the dd-repulsion electric field that tries to keep the deuteron matter in separated-deuteron form. The mathematics uses a screening radius, designated rsc, to measure the range-limiting effect on the dd repulsion force. This screening radius appears in the equation that quantifies the effectiveness of the fermi sea's ability to support the dressing process.

In the first reaction step, several things happen. A selected dd pair meeting "spin-zero" requirements, as specified in the next chapter, segregates itself from the deuteron many-body system and gets neutralized (dressed) by its own 2-electron portion of the electron fermi sea. The isolated dd pair then undergoes a change in its internal structure. The internal geometry of the 2-deuteron system shrinks to nuclear density, either spontaneously or in response to a momentum shock probably associated with a new deuteron changing from localized to quasiparticle geometry, or vice versa. In this stimulated reaction picture, the momentum shock is delivered to the many-body deuteron system and its dressing electron fermi sea matter. The shock momentarily creates a "resonance" condition in which the energy of the total system containing the initial deuteron pair state momentarily equals the total system energy of the collapsed state. The shock causes a transient relative motion between the deuteron pair and its hosting metal, which causes a so-called "momentum scan". The change in dd internal structure is accompanied by a small transfer of momentum to the hosting metal.

The second step is the transfer of 23.8 MeV of nuclear energy from the quasiparticle helium nucleus to the hosting metal. The shock transfer of momentum described above makes a potential fusion reaction irreversible. The new helium nucleus is born with its internal nuclear matter in a state of intense internal vibration. From the point of view of the nucleus, the helium-4 is in a highly excited internal state. It is born at a high energy level. After collapse, the internal structure of nuclear matter has the same dd form that it had before collapse. The protons and neutrons describing the internal nuclear structure have retained their paired deuteron form, designated (d,d). The deuterons have retained their proton-neutron bonds. This (d,d) nuclear structure can also be written (pn,pn). The most stable form of helium-4 nucleus has an internal structure which has mainly neutron-neutron plus proton-proton bondings. This lower energy, more stable configuration can be written (nn,pp). The de-excitation transfer of 23.8 MeV of nuclear energy to the outside world is thought to occur in a cascade of discrete steps. It is thought that these transfers are accompanied by momentum impulses given to the hosting metal lattice at the edge limits of the good interface area, where the interface encounters the larger enclosing metal. The electron screening (dressing) becomes impaired at the edge boundaries of the good crystallite interface area. It is thought that momentum impulses should also occur perpendicular to the interface.

Regardless of process details, reaction energy cannot be released in the form of energetic particles or gamma rays. These conventional emitted quanta have point-like geometries which do not match onto the lattice geometry of the partitioned nucleus form. The geometric mismatch guarantees that the cold fusion process is radiationless. (See Reifenschweiler disussion on p. 17)

Geometries Compared

Fig. 3.4,1 illustrates the deuteron quasiparticle orbital geometry that makes cold fusion possible. The top row shows calculated spatial distributions of adsorbed H atoms located on two different faces of Ni surface crystal. Since the H and D chemistries are the same, the Figure compares the chemical orbital of a deuteron confined within a potential well with that of a deuteron quasiparticle orbital. The right side picture applies to the deuterons that are responsible for cold fusion. The deuteron has adjusted to the 2dimensional symmetry of the surface crystal. The bottom row drawings show the difference between 2 deuterons in adjacent chemical orbitals and 2 paired deuteron quasiparticles. The 2 adjacent chemical orbitals resemble a D2 molecule, whereas the paired deuteron quasiparticles resemble spin-paired electrons. The paired deuteron quasiparticles share the same volume. In quantum language, they have "overlapping wave functions".

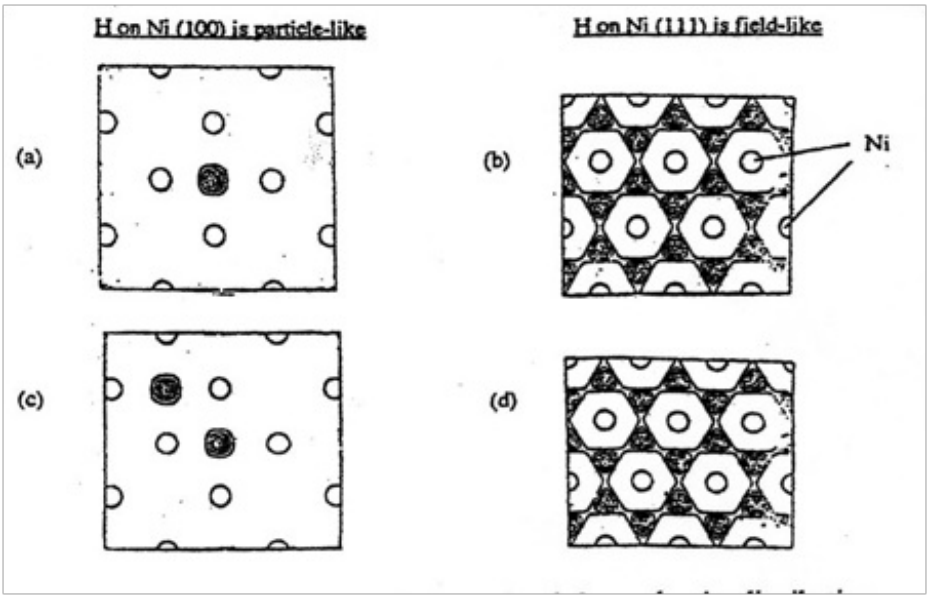

Fig. 3.4,1 The figure is based on calculated charge density distributions of H+on Ni surfaces by R. Nieminen. 1a shows the chemical orbital of a H+ion confined within a potential well on the Ni crystal surface designated (100). 1b shows the quasiparticle orbital of an excited state H+ion on the Ni crystal surface designated (111). The quasiparticle H+ion (proton) is coherently partitoned among a large number of potential wells. These calculations apply equally to deuterons. 1cillustrates the geometry of two deuterons confined within adjacent potential wells on Ni (100). 1d illustrates the geometry of two coherently partitoned quasiparticle deuterons confined within a large number of potential wells on Ni (111). The two coherently partitioned quasiparticles share the same volume, have wave function overlap, and are able to fuse their internal structures in response to the nuclear strong force attraction.

Listening to Molecular Quantum Mechanics

The mathematics that permits calculation of the electron energy density distribution in an orbital uses Schrodinger *wave equation + wave function* physics. The wave function calculations resemble the classical physics calculations of the resonant tones of musical instruments. The mathematical solutions are called eigenstates, and the system energies are called eigenvalues. The configuration that corresponds to the lowest system energy is the ground state orbital. A chart showing the separations between allowed quantum-state energies is called an energy level diagram. The energy level diagram for the hydrogen atom was first calculated by Niels Bohr.

As wave function physics advanced and more complicated atoms were modeled, it became evident that predictions based on calculated orbitals did not match the organization of elements based on chemical properties, as shown in the Periodic Table. But the results did agree if there could be two electrons per calculated orbital. The second atom in the Periodic Table is helium. The ground state helium atom has 2 electrons in hydrogen's *s*orbital. The *s*-orbital is shown in Fig. 1.2,1. The number

of atoms per orbital was doubled. The doubling of the number of atoms per orbital required introduction of the concept of electron spin. The existence of spin meant that there was an additional degree of freedom present in the electron. This additional degree of freedom is also present in other fundamental particles, like protons and neutrons.

The idea that fundamental particles are point objects is not consistent with Heisenberg's uncertainty principle, which says that if you precisely define a particle's momentum, you can't give it a zero size. You must give it a small sub-submicrosopic "size", which gives it a moment of inertia and an associated degree of freedom. The point physics of submicroscopic objects, like idealized electrons in atoms, distributes the particle density of each of the electrons over a 3dimensional continuum of space. The physics of real electrons recognizes that the non-point nature of the electron adds another degree of freedom. Experiments show that the new degree of freedom is restricted to two discontinuous values. Mathematically, the two values are represented by two allowed spin angular momentum vectors (arrows). The electron has been arbitrarily assigned an allowed spin magnitude with index number = 1/2, with a choice of two directions for the spin angular momentum axis . An electron with spin direction "up" is said to have spin +1/2, and an electron with spin direction "down" is said to have spin -1/2. In the helium atom the two electron spins have opposite directions. Their spin angular momentums cancel. The electron pair is a spin-zero pair.

The first orbital calculation that gave the known energy for the helium atom was achieved by Hylleraas. The physics requires that the modeler follow a second Pauli rule, which requires that a 2-particle spin-zero system obey a symmetry constraint called "coordinate exchange symmetry". A 2-particle system of point objects has 6 degrees-of-freedom, which can be taken as the xyzspatial location of the center-of-mass of the combined system, plus 3 degrees-of-freedom to describe the internal dynamics of the 2-particle system. If the internal geometric structure is that of a diatomic molecule like D2, the internal degrees-of-freedom express stretching vibrations along the system axis, plus two tumble modes about perpendicular axes. The Hylleraas solution has a different form. With the Hylleraas solution the energy minimizing solution has an internal structure with zero-separation between the 2 electrons, and no tumble or vibration motion. Instead, the two electrons of the helium atom overlap each other. If the electrons had the nuclear properties of deuterons, they would fuse.

The lesson for cold fusion is that if deuterons are going to be able to fuse at room temperature and pressure, they need to be subject to Pauli's requirement for coordinate exchange symmetry. This condition can be achieved under steady state conditions only if the energy-minimized solution of a 2-deuteron wave equation has the coordinate exchange symmetry form. Energy minimizing calculations show that this condition is satisfied if the deuterons have a quasiparticle geometry and the number of lobes in the quasiparticle wave function "orbital" exceeds about 1000.

As stated above, a two quasiparticle deuteron system has six degrees of x,yz freedom. One best thinks of the two deuterons as a single entity, and describes it in "center-of-mass,separation coordinates". One uses a position vector **r**cm to describe the density distribution of the 2-deuteron entity in the metal lattice, and a separation vector **r**12to describe the repeating internal structure that separates quasiparticle2from quasiparticle1. The six degree-of-freedom wave function is written as the arithmetic product Y(**r**cm) g(r12). In this math Y(**r**cm) is the orbital wave function described in Chapter 3.4, and g(r12) expresses anticorrelation, instead of the vibration and tumbling dynamics of the D2molecule. Function g(r12) modulates the amplitude of the composite 2-deuteron system. Approximate calculations show that g(r12) has essentially the value 1.0 when the number of orbital lobes is much greater than 1000, and a lower value when the number of lobes is smaller, but above a threshold number.

The form of g(r12) is that of a "cusp function". Figure 3.5,1 pictures Y(**r**cm) and g(r12) before fusion. The dips in the green g(r12) function have sharp downward-facing points at their bottoms. One of these sharp points occurs in each unit cell of a "2deuteron internal structure mathematical lattice". Function g(r12) modulates the amplitude of the 6degree-of-freedom wave function at each point in the 3-dimensional deuteron quasiparticle-occupied lattice, as defined by Y(**r**cm). Figure 3.5,2 shows the change in g(r12) geometry that occurs during the wave function collapse step in the

fusion process. This collapse is Step 1 in the nuclear reaction process.

Another important discovery in molecular chemistry and physics has been a recognition that the geometry of a molecule can be made to change to a second geometric structure that has almost the same energy. The condition producing this change is called a Feshbach resonance. The change occurs during an energy scan process. If one can alter the environment in a manner that changes the energy of one of the configurations differently from the other, one can at some point make the two energies equal. The energy changing process is called a resonance scan. A scan across a resonance can switch the system's internal geometry, leaving the location of the center-of mass unaffected. The physics of molecular quantum mechanics shows that a back and forth scan across a resonance can lead to an energy transfer to the hosting environment. As applied to the quasiparticle nuclear states involved in quasiparticle deuteron fusion, the scan process can lead to a transition from a pre-scan paired deuteron state to a pre-scan near-resonance metastable initial nuclear state, accompanied by transfer of a small amount of energy and momentum to the hosting metal environment. The metastable nuclear state is a high-energy excited state, many MeV above the helium-4 ground state. However, the transfer of even a small amount of energy to the hosting lattice makes the nuclear reaction irreversible. The possible role of nuclear resonance was pointed out by Xing-Zhong Li, the head of the Chinese cold fusion effort. Physicist Scott Chubb identified momentum shocks as a means of transferring energy to the hosting environment. A subsequent energy cascade process completes the transfer of nuclear fusion energy to the hosting lattice.

Six Degree-of-Freedom Quasiparticle Wave Function

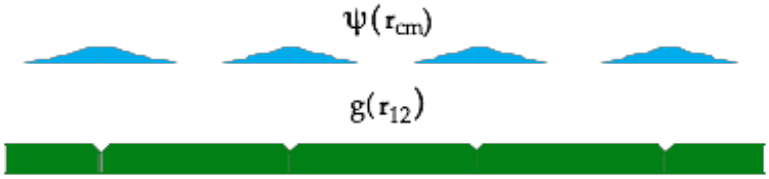

Fig. 3.5,1 Wave function amplitude in physical space Y(**r**cm) and wave function modulation factor in separation space g(r12)for a 2 quasiparticle deuteron entity.

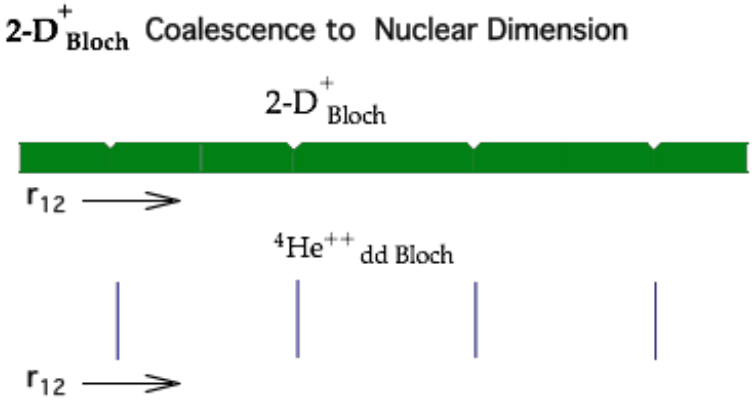

Fig. 3.5,2 Collapse transition of a quasiparticle 2-deuteron pair. The green image is the g(r12)internal geometry function before collapse to nuclear dimension. The four blue vertical lines is the g(r12) function after collapse to nuclear dimension.

Listening to Nuclear Physics

Nuclear physics began with the discovery of radioactivity and with Marie Curie's proof that its source was a new element called radium. Nuclear physics as an experimental science began with Rutherford's alpha particle scattering experiments that showed that an atom's positive charge is concentrated in a tiny nucleus at the center of an atom. The growth of nuclear physics up until the discovery of neutrons and their use to create new elements was dominated by high energy scattering experiments, which are direct descendants of Rutherford's work. All of these involve an interaction at a central point. This highly successful tradition makes the concept of quasiparticle

nuclei almost impossible for nuclear physicists to accept. Nonetheless, it is important for cold fusion scientists to listen to the nuclear physics community.

Nuclear physics has provided a deep understanding of the internal structure of the nucleus, its internal dynamics, and the mechanisms by which an unstable nucleus emits decay products. The geometry of alpha particles, neutrons, electrons, gamma rays, positrons, neutrinos, etc. must match onto the initial and final nuclei participating in any nuclear decay process. Nuclear physicists have classified various ground and excited states of nuclei much like atom chemists and physicists have done with atoms and molecules. Spin, angular momentum, and wave function (orbital) symmetry are used in their classification scheme. Reactions are labeled in terms of initial and final states (feedstock and product). The cold fusion reaction involves two quasiparticle deuterons combining to produce one quasiparticle helium-4. Nuclear physics call this type of reaction a 0+ to 0+ transition.

The 0+ to 0+ transitions are relatively slow transitions if the initial and final states are separated by a small difference in energy. The lifetime of the initial state becomes especially long if the energy difference is very small, which is the situation that exists when the reaction product is produced by a resonance scan. This relatively long lifetime suggests that momentum shock stimulation plays a role in the cold fusion process . McKubre's formula for fusion heat production shows that deuterium inflow and outflow are needed for production of detectable heat in his experiments. His empirical formula supports this view.

Nuclear physics scattering experiments have shown that reactions induced by charged particles striking a nucleus occur only when the incident particle has high energy. The studies show that reaction rate decreases rapidly with particle energy, falling close to zero by 1000 electron volts. At room temperature, reactions are clearly impossible. This conclusion is undeniable as long as the reaction geometry is the same as used in nuclear physics scattering studies. That is why deuterons must have a quasiparticle form if cold fusion reactions are to occur at normal metal densities and temperature.

The key characteristic of quasiparticle geometry is that the quantum-of-mass called a deuteron must occupy a many-lobe orbital. Ideally, each lobe is an equivalent potential well. In Rutherford scattering experiments there is a single identifiable location where an energetic particle recoil event has occurred. In Rutherford-type scattering experiments which result in a nuclear reaction event, there is a single identifiable location where the nuclear reaction has occurred. In contrast, in the cold fusion quasiparticle case there is no single location where the reaction takes place. Instead, the reaction takes place coherently and simultaneously at many locations. In the Rutherford scattering experiments one has a single-center target nucleus. In quasiparticle fusion one has an overlapping pair of many-centered deuterons which becomes a many-centered helium-4 nucleus. The Penrose interpretation of Schrodinger wave functions supports the reality of the quantum-of-mass picture in submicroscopic physics.

The cold fusion reaction is a catalytic reaction in which the physical form of the deuteron feedstock is converted from localized particle form to a lattice geometry form prior to reaction. In the lattice form, the deuterons are "coherently partitioned", which means that there is a fraction of each deuteron present in 1000 or more separate small volumes. These deuteron fractions are "entangled", which means that their mathematical sum is the mathematical original deuteron.

Cold fusion liberates nuclear energy in the form of heat by converting 2 deuterons into a helium-4 nucleus. The reaction liberates 23.8 MeV of energy per fusion event, which is about one tenth the energy liberated by splitting a uranium nucleus. Compared with uranium fission, cold fusion produces roughly 6 times more energy per pound of fuel.

As shown below Figure 3.6,1 illustrates the quasiparticle dd reaction. In the artist drawing, the initial state is the state which shows the paired deuteron quasiparticle located at an energy level 24 MeV above the helium-4 ground state. The 24-MeV level marks the energy of the quasiparticle deuteron pair both before and immediately after contraction to nuclear dimension, as described in Chapter 3.5. The amount of energy transferred during the resonance scan responsible for the contraction is

too small to show on the chart. The stacks of small horizontal bars designate energy levels in a standard energy level diagram. The spacing between bars are the differences in excitation energy between adjacent vibration states inside the nucleus. The energy spacings within each of the vertical stacks are uneven and of the order of 100,000 electron volts. The adjacent stacks of horizontal bars are for the two internal geometries described in Chapter 3.4, namely a (d,d) pairing geometry and a (pp,nn) pairing geometry. A (dd) pairing is the same as a (pn,pn) pairing. These nucleon pairings are like the zero-spin electron pairings in atoms. The pairings create spin-zero pairs from half-spin fundamental particles, as discussed in Chapter 3.5.

The two stacks of energy levels on the left compare the excitation states for a normal single-center nucleus with the two stacks of energy levels on the right, which show the corresponding excitation states for a many-centers nucleus. Note that the 0+ ground states for the (d,d) nucleus are at different levels. This difference in ground state energies is due to the reduction in work energy required to contract two deuterons to nuclear dimension in a many-centers helium-4 geometry as compared with the work energy required to contract two deuterons to nuclear dimension in a single-center geometry. Note that the partitioning of a (pp,nn) nucleus does not alter nucleus energy, because the (nn) pair has zero charge. There is no coulomb repulsion force between a (pp) pair and a (nn) pair. As a result, the (pp,nn) helium-4 many-centers ground state has the same energy as the (pp,nn) helium-4 single-center ground state.

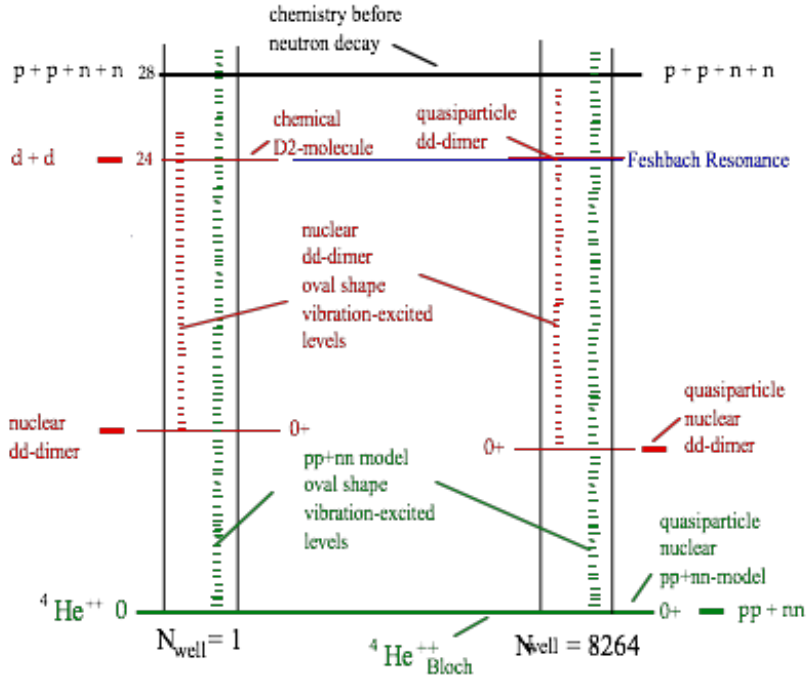

Fig. 3.6,1. Energy level chart for two internal structures of helium-4, and a comparison of energy levels for a single-center nucleus vs. a quasiparticle multi-center nucleus containing 8264 potential wells (orbital lobes). The initial paired deuterons before collapse to nuclear dimension is at 24 MeV above the ground state helium-4 nucleus. If one started with 2 free protons and 2 free neutrons, the starting state would have been 28 MeV above the helium-4 ground state.

Listening to Roger Penrose

Quantum Mechanics was developed to correct deficiencies discovered in the Maxwell-Faraday theory of electromagnetism. Maxwell's equations explain the generation of electromagnetic radiation (radio, infrared, visible, ultraviolet, x-rays, gamma rays) but were unable to explain the color spectrum of light emitted by hot metals and the sun. It was also unable to explain the existence of atoms consisting of a massive nucleus and a 2000 times lighter electron. It said that the electron should continuously lose energy and "fall" into the proton. The quantum theory provided a solution to the energy loss problem, and made quick progress in creating models that predicted the ultraviolet, visible, and infrared emission line spectrum observed. But the physics was hard to accept by many scientists. It seemed to violate common sense when the physics said you can't describe a particle's position and momentum at the same time (Heisenberg uncertainty principle). When multiple-particle systems were modeled, one had to add 2 Pauli constraints: the exclusion principle and the requirement for coordinate exchange symmetry. Also, certain compound particles were able to avoid the Pauli exchange rules. One had to add spin as a new "quasi-degree-of-freedom" to explain the Periodic Table of Elements. Spin also explained the existence of double line emission as seen in sodium vapor lamps.

The apparent violation of common sense and classical logic has led to endless arguments about the nature of Quantum Reality. It became popular to interpret the orbitals of chemistry as probability distributions, which permitted an experimenter to predict where a point-particle would be most likely found in a scattering experiment. This probability function description is called the "Copenhagen interpretation". Enrico Fermi avoided these philosophic discussions and just went ahead and used the wave equation and wave function to calculate expectation values for experiments. Nonetheless, the philosophic argument continues today.

Mathematician Roger Penrose takes the minority view that a wave function is much more than a probability distribution. Penrose is considered one of our greatest living scientists. He is Emeritus Rouse Ball Professor of Mathematics at Oxford University. His 2006 book "The Road to Reality" discusses his quantum reality views. His interpretation makes use of the concept of wave function collapse, which supports the electron density interpretation of an atomic orbital. When an incident xray hits an electron orbital it can cause a wave function collapse. The wave function collapse to point size is most likely to occur where the particle density is highest. The correlation between calculated electron density and collapse point is a common sense explanation for the success of the probability interpretation. This book accepts Penrose's wave function collapse picture. Penrose calls the collapse "a state reduction" and designates it by the symbol **R**. Prior to collapse a state can have a weakening density and growing volume, which he calls "unitary behavior" (Schrodinger) evolution, designated **U**. A picture of the time evolution of a state is shown in Fig. 22.1 on page 529 of his book.

The theory used in this discussion of cold fusion seems consistent with the physics known before 1989, when cold fusion was announced. The language of chemistry seems especially appropriate, and adequate to visualize the cold fusion process as thus far understood. Treating 2-body systems as 6-degree-of-freedom objects, plus spin, seems to work. Worries about a need to produce a more precise theory should not be permitted to delay development of quasiparticle-based clean energy for the near future.

Role of Asymmetry

It may seem strange to approach the end of this discussion of a symmetry-based reaction model with a discussion of asymmetry. However, there is a parallel with the quantum physics of molecular spectroscopy. Simple molecules with strong infrared absorption are the ones with large dipole moments, like HCl and H2O. Similarly, in nuclear physics, states that differ by 1 unit of angular momentum have relatively high nuclear reaction cross sections because they interact strongly with electromagnetic fields. The first step in a dd fusion reaction is a momentum transfer that occurs during a resonance scan between two energy states. Both the Iwamura CaO + sputtered Pd interface reactions and the Arata-Zhang ZrO2+ nanoPd interface reactions have been shown to be good heat producers. Both provide a highly asymmetrical environment within which a quasiparticle deuterium many-body system can be hosted. The environment has high lattice symmetry in the plane parallel to the interface, and very asymmetric symmetry in the direction perpendicular to the interface, as shown in Figure 3.8,1.

There are in-plane momentum shocks which are generated when migrating deuterons transition from a localized chemical-form to a delocalized quasiparticle form, due to an essentially instantaneous shift in center-of mass. In the oxide-nanometal systems, there are also shocks that are produced in the direction perpendicular to the crystal-metal interface plane. Independent of any fusion reaction shocks, when a deuteron transitions from chemical orbital form to quasiparticle form and suddenly spreads over an interface area that provides 1000 potential wells, it suddenly imposes a jump in deuteron positive-charge density within the interface volume. In response, a 0.001 fraction of an electron quantum-of-mass moves from the metal's fermi sea and enters each unit cell of the same interface volume. The charge neutralization process is called "dressing". The Pauli exclusion principle applied to electron matter requires a sudden jump-increase in the thickness of the interface. This thickness increase forces an "instantaneous" recoil of the adjacent metal relative to the more incompressible bulk oxide crystal.

The migrating deuteron has created an asymmetrical recoil motion which is analogous to the momentum shock that occurs when a many-body solid-state system recoils as a unit during a momentum transfer between two contacting systems. Such momentum recoils are known to occur between crystallites and hosts during the radioactive decay of certain iron nuclei. The phenomenon is called the Mossbauer effect. It is a recoil effect that was discovered when a particular type of iron was hosted inside a solid crystallite. In the Mossbauer effect, the gamma ray emitted from a recoiling radioactive iron nucleus within a crystallite is resonantly absorbed by a non-recoiling non-excited atom of the same iron type located in a second iron hosting solid material, but only if the two systems are physically moving slowly apart at the right relative velocity. The gamma ray then sees a momentum match and is absorbed.

In cold fusion reactors, the asymmetric momentum shock has a different origin and different form from that produced by a Mossbauer momentum recoil. The shock that occurs when a migrating deuteron changes its geometry has an acceleration-deceleration form. It produces a back and forth energy scan between interface and metal host, caused by a back and forth velocity spike. The resulting energy scan appears able to trigger Step 1 of the nuclear reaction process.

Momentum shock events of this type require that deuterons move inside the metal. This need for migrating deuterons seems to explain the reaction stimulation that accompanies deuteron fluxing, as specified in McKubre's empirical law based on his cold fusion heat observations.

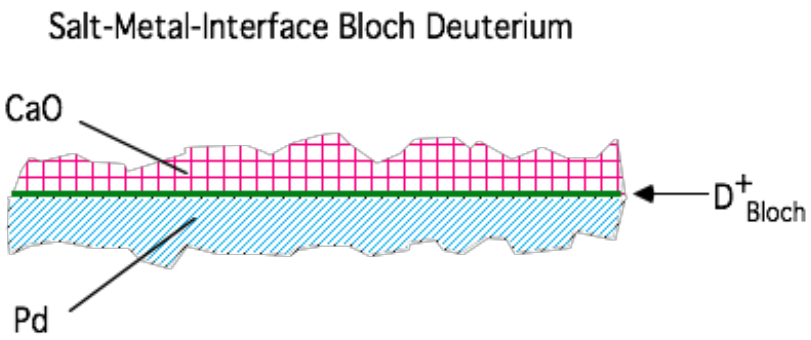

Figure 3.8,1 Asymmetric interface used by Iwamura's group in excess heat observations in 1999. The quasiparticle deuterium which occupies the CaO Pd interface is labeled D+Bloch. The interface provides an environment that enforces 2-dimensional periodic lattice symmetry within the interface plane, and asymmetric symmetry perpendicular. Entry of a deuteron into the interface volume creates a momentum shock perpendicular to the interface due to Pauli exclusion operating on the neutralizing electron matter. The shock provides a momentum scan that aids collapse of quasiparticle deuteron pair to nuclear dimension. This collapse is Step 1 of the nuclear reaction process

Listening to Cold Fusion

In summary, it is no accident that the phenomenon of cold fusion was discovered by chemists. Chemistry and related materials science are the original disciplines of the submicroscopic world. Although the centered-mass geometry of atoms was first discovered by Rutherford in an alpha-particle scattering experiment, the wave function orbitals that fill the atom and form the bonds binding atoms into molecules belong to chemistry and material science. Listening to Rutherford's energetic alpha particle, an atom is mostly empty space; listening to the electrons that pack the atom's volume, the atom is chuck full of matter. This packing is the maximum that is allowed by the Pauli exclusion principle, when subject to system energy minimization. From the point of view of the electron, the atom is a potential-energy well with no free space.

Pauli exclusion is the essential organizing principle of microscopic physics and chemistry. It is central to an understanding of both the Periodic Table of Elements and the internal structure of nuclei. If it were not for Pauli exclusion, all the atoms would look like hydrogen and helium. Pauli exclusion applies to electrons, protons, neutrons, and neutrinos. If one listens to the protons and neutrons, each proton consumes "proton space" and each neutron consumes "neutron space", just like each electron consumes "electron space" in an atom. The nuclei of all elements heavier than helium become larger in volume as one adds more protons and neutrons, just like the atom volume

grows with added numbers of electrons as you move towards the higher atomic-number elements in the Periodic Table. When an attractive force, like the nuclear strong force, the Coulomb force, or gravity, is present and seeks to collapse a system of fundamental particles, the collapse proceeds until there is no free space. Note that the presence of electrons doesn't bother protons and neutrons, and neutrinos only worry about other neutrinos. An astrophysical example is the white dwarf star, where an electron lattice fights against the pull of gravity*. From the electron's point of view, the star's volume is a fully packed sum of electron orbitals. Pauli exclusion prevents collapse of the electron lattice. The electron-filled volume also contains a hot ion plasma. The moving ions co-exist within the electron lattice structure. Even neutrinos are subject to Pauli exclusion. In one model of dark matter, Pauli exclusion prevents collapse of a gravitationally bound lattice of sterile neutrinos, just like it prevents the collapse of the electron support structure of a white dwarf star. Listening to the dark matter neutrinos, the neutrino halo within which our galaxy is embedded is a fully occupied compact volume.

* More accurately, gravity pulls mostly on the ions flying freely through the electron lattice. The gravity pull displaces the positive ions relative to the negatively charged electron structure. The force between the offset positively charged ions and the negatively charged electrons transmits the gravity force to the electrons.

Pauli exclusion is also the controlling principle in metals. There would be no solids of any kind if Pauli exclusion did not exist. A metal's electrons would combine with the embedded metal ions to produce a vanishingly small, high density entity. The physics modeling of a metal seeks a minimum energy solution in which the contraction pull between positive ions and the lighter, more voluminous electrons fight against Pauli exclusion. The resulting balance of forces produces the metals we use in the engineering world. The most effective protocol used by solid state scientists to model metals is called "density functional theory", which is based on the electron density interpretation of wave function amplitude.

Unfortunately, a number of important cold fusion scientists think that the electron density limit established by Pauli exclusion can be circumvented by special cluster geometries. Such cluster models are non-physical.

Interdisciplinary chemistry/physics scientists encounter a wide range of electron configurations and behaviors. Here are 7 of these electron configurations: **1)** the free electron that undergoes elastic collisions with ions in the interior of the sun and in the plasma fusion devices of the hot fusion program, **2)** the confined electron in the *s*orbital of the hydrogen atom ground state, where it has existed unchanged in cold interstellar gas for 10 billion years, **3)** the coherently split hydrogen that resides equally in the two lobes in the *p*orbitals of the boron, carbon, and nitrogen atoms, **4)** the aromatic hydrocarbon ring electron that shares the 6-lobe orbital of the benzene molecule with 5 other electrons, **5)** the 2dimensional lattice symmetry electron that shares a million-lobe orbital with a million partners in a sub-micron graphene* crystallite, **6)** the 3-dimensional lattice symmetry electron that shares 10101015potential wells with 10101015other electrons in a microscopic metal crystal, and **7)** the 1024electrons sharing 1024potential wells with more than 1024fermi-sea partners in a gram molecular weight of multi-crystalline bulk metal. These diverse morphologies are different forms of "the quantum-of-mass of electron matter". The quantum-of-mass of electron matter is called a particle when it is a free-flying entity in a hot plasma, and called a quasiparticle when it is a partner in an electron fermi sea, or when it is a conduction entity in a semiconductor. Similarly, the deuteron is a quantum-of-mass of deuteron matter. It has particle form when it serves as the nucleus of a deuterium atom, or when it serves as one of the pair of nuclei in a D2molecule. It has quasiparticle form when it serves as a partner in a dd cold fusion reaction. In its 2-dimensional symmetry quasiparticle form, it most closely resembles the quasiparticle electron hosted by a sub-micron graphene crystallite.

* Graphene is a graphite crystal that is one atom-layer thick. The existence of graphene was discovered only a few years ago.

Returning to rules that govern the submicroscopic world, there are two additional physical principles

that affect Pauli controlled structures. Thefirst of these is the famous Heisenberg uncertainty principle. One thing that the uncertainty principle says is that the mathematical* ideal point particle is an abstraction that does not exist in the submicroscopic world. It says that even the electron, which is sometimes almost a point particle, has a non-zero moment of inertia, whereas a mathematical point object has a zero moment of inertia. Each of the fundamental particles: electron, proton, neutron, and neutrino, have both a non-zero moment of inertia and a rotation about this moment of inertia axis called spin. This combination means that near-point objects have angular momentum. Spectral observations show that the spin angular momentum can have either of two orientations: it can be "up", designated 1/2, or it can be "down", designated -1/2. These options constitute a new, but limited 2-value degree-of-freedom. Where you could put one electron before the discovery of spin, you could put two electrons after the discovery of spin. The spin choice doubles the number of electrons allowed in each orbital of the maximally packed atoms making up the Periodic Table. Because of spin pairing, half the pairs of conduction electrons in a metal overlap each other, despite their mutual repulsion. Metals have twice the density that they would otherwise have. Nonetheless, the discovery of spin does not change the primary controlling role played by Pauli exclusion.

The non-physical nature of the submicroscopic mathematical* point, combined with Pauli exclusion, leads to the possibility of spin-paired composite particles. One example is the spin-zero double electron that fills the lowest energy orbital of the helium atom. The spin-zero electron pair provides the most densely packed, minimum energy electron matter structure available to neutralize the helium atom's double-charge nucleus. In this pairing the two electrons have canceling spins and coinciding positions in physical x,y,z space. The 2 electrons sit on top of each other. If they were subject to the nuclear strong force attraction, they would fuse. When this mutual overlap configuration applies to deuterons, it creates the geometry that makes deuteron cold fusion generate heat. Unlike spin-zero paired electrons, spin-zero paired deuterons are subject to the nuclear strong force attraction. When they have an overlapping 2particle wave function, the strong force attraction pulls them together to form a helium-4 nucleus with the same multi-lobe quasiparticle geometry. The reaction takes place at a multiplicity of points instead of at a single point. The 2-deuteron overlapping form of wave function is favored by energy-minimization mathematics if the number of lobes (potential wells) exceeds about 1000. It is interesting to note that the deuteron quasiparticles of the metal oxide + nanometal composites used by Iwamura's team, and probably also those used by Arata and Zhang, have a 2-dimensional lattice symmetry similar to that of the quasiparticle electrons in graphene.

* As in Penrose's Platonic mathematical world. See Roger Penrose, *The Road to Reality*, Chapter 1.

Listening to cold fusion tells us how we can proceed to develop commercial cold fusion heaters and other devices. The problem has been: How do you get deuterons to behave like electrons in a metal? Two decades of experimentation tells us that the same type of overlap can be achieved with deuterons. Another thing the experimental studies have told us is that reactive deuterons do not need to reside in orbitals containing an incredibly large number of orbital lobes (potential wells), such as are routinely occupied by electrons in metals. Experimenters can use the flexibility of metal nano-structures to meet the deuteron's need for the more easily achieved lower number of potential wells required for multi-lobe orbital deuteron fusion.

The Japanese cold fusion experiments using metal oxides and nanometals suggest the presence of a nuclearly reactive deuteron material coating a metal oxide. Envision a coating of 30 deuterons plus 30 neutralizing electrons spread out over a 2000-atom surface of CaO crystal. This material would be a polarizable, electrically neutral coating with a thickness less than 3% of the thickness of the adjacent metal monolayer. All of the coating's thickness is due to Pauli exclusion acting on the electron matter component of the electrically neutral deuterium system.