

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 2-dimensional 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 $10^{10} - 10^{15}$ potential wells with $10^{10} - 10^{15}$ other electrons in a microscopic metal crystal, and **7)** the 10^{24} electrons sharing 10^{24} potential wells with more than 10^{24} fermi-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 D_2 molecule. 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. The first 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 2-particle 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. The polarizability of the coating helps stabilize the interface and minimize system energy, just as polarizable water layers stabilize metal ions in solution.

Cold fusion experiments have confirmed the very large amount of energy predicted by theory for a nuclear fusion reaction. This large energy release means that only a small reaction volume within a much larger volume of reactor material needs to be nuclearly active. As a result, a multiplicity of 2-dimensional interface volumes provide sufficient reaction volume for most applications. The nano-palladium work of Arata and Zhang, and the independent work of Iwamura's group, show two different ways to create and maintain nuclearly reactive deuterium. Building on these methods can give us the abundant clean energy the world will need within the next decade. We must somehow obtain the funding needed to support cold fusion heater development.