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Research Article

Pictorial Description for LENR in Linear Defects of a Lattice

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Abstract

This note provides a pictorial description of several new concepts in low energy nuclear reactions (LENR) and thereby provides an image for both theoreticians and experimentalists to better grasp the differences with the old. Recent work on the concept of a 'linear hydrogen molecule within a lattice defect' is emphasized by showing how the interatomic spacing of the unusual molecule is no longer bound by the lattice spacing. A concept of the nature of the Coulomb potential for finite-sized charges at nuclear distances is pictured so that people stop clinging to the point- and separated-charge descriptions that are no longer appropriate. A known force, spin-spin coupling, may be important when dimensions approach those of the nucleus. The strong magnetic moment of the electron, indicating the importance of this effect at larger distances, is also pictured.

Keywords: Cold fusion, Coulomb potential, Linear array, Nuclear Coulomb potential, Spin–spin coupling Variable lattice spacing

1. Introduction

Too often technical papers are full of equations, with which many experimentalists are not comfortable, or full of data with no expressed consolidating theme with which to draw the results together. Cold fusion (CF) is more often rejected because of 'known' physics than because of new ideas required to explain the experimental observations. It is hoped that some pictures might help to explain things.

The concept of lattice spacing is one of the foundations of solid state physics. This concept, including the lattice and Coulomb barriers preventing hydrogen atoms from approaching one another in a lattice, is a major argument against the possibility of proximity-induced fusion. The standard view is that H atoms are bound to specific sites and vibrate within that location. The Einstein oscillations [1] about a central point fixed in the lattice are small compared to the fixed spacing between adjacent sites. Thus, the thermal effects (even collectively as phonons) are never adequate to bring H atoms close enough together to account for the heat or fusion rates observed experimentally. A linear-defect mechanism has been proposed that overcomes this limitation [2–4]. However, the first of these papers to identify a change in lattice spacing as the solution to this problem provided only a mathematical model as to how this would overcome the Coulomb barrier in this manner. It did not provide a mechanism for achieving this change in lattice spacing. The second of these papers [3] identified a location (a specific type of defect) that could be the source or site of

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CF within a material. The author, Ed Storms, being a chemist was unable to present a convincing story to the physicists of the CMNS community. In some cases, he was facing the problem of 'things too-well known'. In others, it was his inability to use the concepts that were a common language to the physicists. The third paper [4] sought to bring these theoretical and 'practical' concepts together, along with some concepts introduced by Schwinger in the early 1990s [5]. This present paper will provide pictorial representations to help visualization of the distinction between the standard view and the new, and perhaps necessary, concepts for bringing hydrogen atoms close enough together for fusion rates predicted by observed CF results.

Another issue that will be expressed pictorially has no meaning for most physicists. It can be expressed; but it still leaves questions. How does the Coulomb potential change when an electron is within the nuclear-potential region? At what point do paired fermions become a boson? What is the meaning of 'radius' for electrons and protons?

The third issue that will be expressed pictorially, spin-spin coupling, has not been raised/expressed in the context of CF. In atomic physics and chemistry, spin-orbit coupling [6] is a weak magnetic interaction between an electron's magnetic moment and the magnetic field resulting from its orbital motion. It is an important feature of electron interactions at this level. At nuclear dimensions, where the nuclear magnetic moments and possible orbits are much smaller, this coupling may be important for nucleons.

Spin-spin coupling [7] is the interaction of the magnetic fields associated with the spin of separate charged particles. At atomic orbital distances, this may be a barely noticeable effect. At nuclear distances, even the low-magnetic-moment nucleons can interact in this manner. However, at the intermediate distances between the atomic orbitals and the nucleus, the strong magnetic moment of the electrons can produce a very important force between electron pairs. This could greatly alter the interaction of colliding atoms, if the atomic electrons drop deeper into the charge potential well during the collision. This picture influences the expectations for both the Lochon [8] and the Linear-Hydrogen Molecule Models of CF [4].

2. Variable Lattice Spacing

The fixed lattice spacing, ℓ, of conventional solid state theory is displayed in Fig. 1A with the Einstein oscillations (with amplitude 'a') superimposed. The linear array indicates the spacing between of a vertical array of atoms in a lattice.

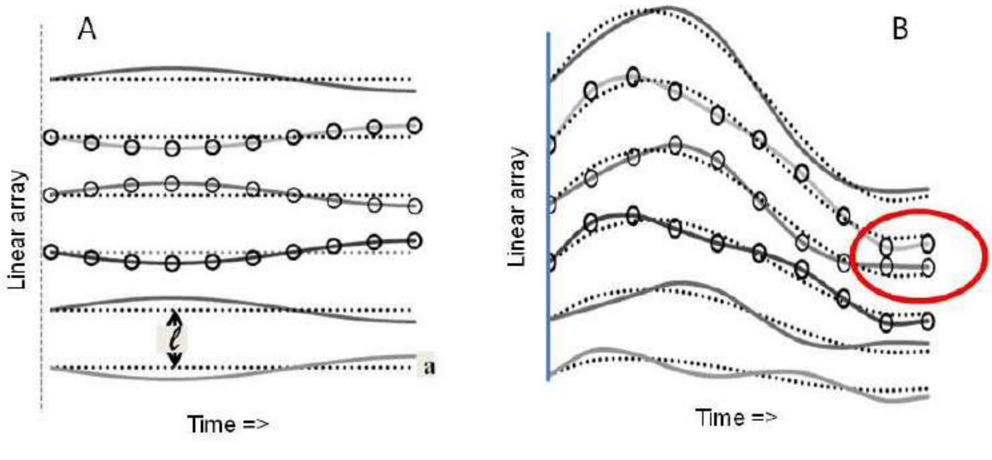

Figure 1. Fixed and changing lattice spacing. (A) Einstein oscillations about *fixed* lattice points. (B) Oscillations with *varying* lattice spacing.

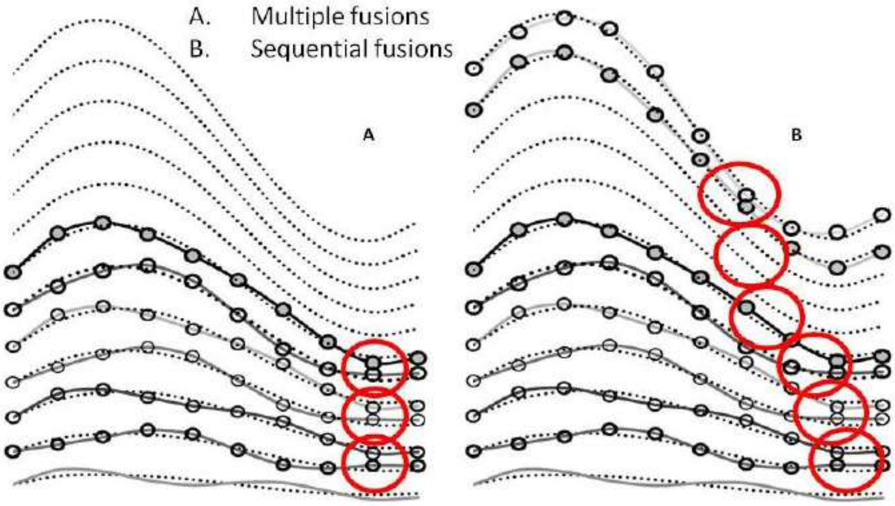

Figure 2. Variable Lattice spacing (displayed as dotted lines for a vertical lattice array stepped in time). (A) Multiple fusions. (B) Sequential fusions.

This array is propagated to the right with steps in time. The oscillations about the fixed lattice represent longitudinal optical photons with adjacent atoms 180° out of phase. This means that the distance of closest approach between atoms is $\ell - 2a$. The circles (of radius δ) represent the interaction distance about the atoms (not to scale) at which fusion has a high probability.

Figure 1B is similar except that the lattice spacing, ℓ', is now allowed to vary with time. If a lattice spacing varies in an oscillatory manner, and the oscillations can increase in amplitude with time, then there will be a point (e.g., circled region) where the variations in lattice and Einstein oscillations are properly phased so that $\ell' - 2(a) < 2\delta$ and fusion will occur.

The difference in Figs. 1A and B represents the differences in sub-lattice atomic arrays that are confined by the rigid structure of a 3-dimensional lattice and linear arrays that are only confined laterally. The linear array can vary its interatomic spacing; but this capability is seldom modeled in physical structures. It cannot occur in a normal 3-D lattice. This is an important point that Storms made – based on his study of the CF experiments and data over many years. This is not to say that the lattice does not affect the defect-isolated linear array. It says that the lattice influence does not dominate the phonon-induced motion along the array.

If the number of atoms in the linear array is increased (from Fig. 1B), then it is possible to have multiple fusions occurring at the same time (circles in Fig. 2A). In fact, multiple fusions can occur sequentially at different points along the linear array (Fig. 2B). It is possible that the energy released by a single fusion can boost the rest of the array into a more confined configuration that would create fusion reactions of many or most of the atoms in that region of the array. This could account for the 'thermal craters' often observed in solid-Pd electrodes that have produced excess heat.

2.1. Consequences of Change in Lattice Spacing

Figures 1 and 2 provide a picture of the variable-lattice array changing its spacing as a function of time and identify points at which fusion can occur. Mechanistically, it indicates the proximity coupling of lattice phonons with the nuclear potential (Schwinger model [5]). The phonons drive both the Einstein oscillations and the lattice oscillations.

The oscillation amplitude can grow in time. It can be stable, but then be ‘triggered’ by some event over a threshold. If the nuclei get close enough together, the nuclear potential can provide an impulse that can increase the amplitude of oscillation. This is equivalent to an increase in the number of phonons. These new phonons are generated from the nuclear potential energy. Since phonons are bosons, they seek to get into the same state (including phase) and this would result in greater amplitudes of the respective modes. This is a positive feedback mechanism that would ultimately result in fusion of H atoms in the linear array.

A major contribution to this scenario by Schwinger was the concepts that the nuclear potential must be included in the Hamiltonian of the linear array and that this energy source could be used to increase the specific phonon modes driving the array into close-spaced positions. He could not convince his fellow physicists of this new approach, despite his use of quantum mechanics, being a Nobel Laureate, and being one of the best theoretical physicists of his time.

3. Coulomb Potential at Nuclear Distances

Fifty years ago, in his Lectures on Physics, Feynman wrote (in paraphrase) “the Coulomb potential has been shown to be valid up to the nucleus.” The understanding among some mathematical physicists seems to be that it is valid to $r = 0$. They seem to ignore that, if this is true, then every particle with a potential obeying this $1/r$ potential must be a singularity (with infinite energy). However, they reject a solution of the Dirac equations that is singular at $r = 0$. Since Cold Fusion results violate many theoretical arguments, let us examine this one more closely.

Starting with the creation of an electron-positron pair from a finite energy photon (1022 keV $< E_\gamma < \infty$), we can assume that the combined relativistic mass of the pair is less than infinite. Thus, the Coulomb potential fails at $r = 0$. Yet, nearly all quantum mechanics Hamiltonians, using the $(1/r)$ Coulomb potential, do so without comment. This seldom causes a problem since throwing out any solution that does not go to zero at $r = 0$ appears to be an appropriate process. For over 50 years, anytime someone suggests (in a journal) that perhaps the ‘anomalous’ solution of the Dirac equations (non-zero at $r = 0$) should not be thrown away, papers are immediately published showing that solution to be invalid. In the 21st century, it may not be possible to even publish a paper indicating that the anomalous solution may be valid. In 2005, Jan Naudts was able to get such a paper[a] posted in the ‘arXiv’ [9]. However, while his paper could not be published in a journal, two papers rejecting his work were able to be published in an established physics journal (Physics Letters A). An earlier paper [10], which gave a finite value at $r = 0$ for a Coulomb-like potential in the Dirac equations, was published in Fusion Technology (not a journal that mathematical physicists would read) and only received rejecting papers from a single source. However, the rejection was not based on the normal mathematical ‘niceties’. It was based on a physical reason: the low probability of the anomalous solution having any observable effect.

With this background, let us examine the potentials in the nuclear region. We start with an assumption: the Coulomb potential cannot exceed the mass of the particle producing it. This would mean that the potential energy for an electron cannot exceed 511 keV. (Assume also that any relativistic mass is electromagnetic and therefore not contributing to the charge mass.) In the far field, the electrostatic potentials of a proton and electron are identical, $V_\mathrm{p} = V_\mathrm{e}$. In the near field (i.e., inside the nucleus), the electrostatic potential can continue to grow until limited by the mass and/or effective radius ($R_\mathrm{p} =\sim 0.88$ fm). The potential of the electron loses its $1/r$ dependence at a larger radius ($R_\mathrm{e} =\sim 2.8$ fm), below which $V_\mathrm{p} > V_\mathrm{e}$. Details of this development of a mass-dependent potential are the subject of a different paper.

3.1. Shapes of electrons and protons

When using the concept of size for a proton or electron, there is a lot of ambiguity. For a proton, the radius is considered to be on the order of 0.88 fm. The measured nuclear potential is the primary (and logical) determinant of this dimension.

[a]He used the Klein–Gordon equation rather than the Dirac equations. However, the intent and result is the same.

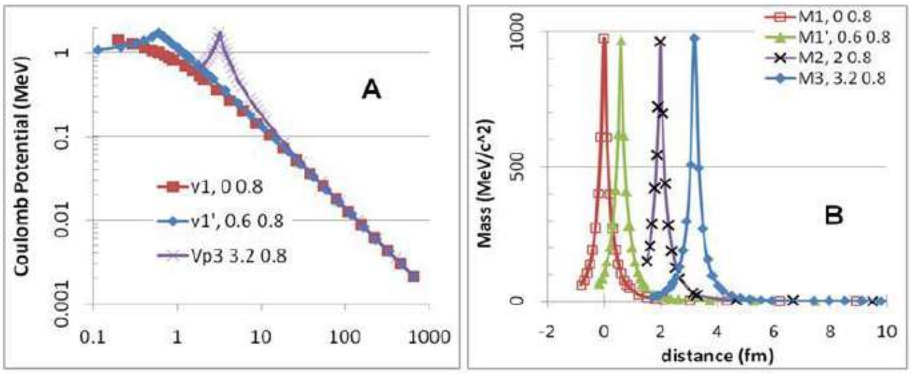

Figure 3. Proton 'shapes' for (A) potential and (B) mass energies of protons at various distances (0, 0.6, 3.2 fm) from the origin.

If we were to consider the electrostatic potential to define the radius, then there is a possible problem since there is no well-defined edge to measure. In Fig. 3 we have defined the shapes to be finite at $r = 0$. The electron has a maximum potential energy of 511 keV at $r = 0$ with a 'turnover' at the classical radius. The proton has a larger maximum; but, as a compound structure, its energy density integrated over the effective volume must still be that of its mass.

Figure 3A gives the shape of this potential on a log-log plot for three different locations. The shape is not symmetric on this type plot. However, it indicates that the far-field (> 30 fm) potential is not very sensitive to the shape and location of the charge within this nuclear range.

The shape and magnitude of electrons and protons, based on charge potential, are identical in the far field. So in some sense, it could be said that they are the same size. Only within the 10 fm range (for this model) do they differ. Often the electron radius is defined by its Compton radius ($\sim$ 380 fm). In this figure, the potential at that dimension corresponds to about 0.1% of the peak value. If, instead of the potential, we select the mass energy of the proton as the determining factor, then Fig. 3B (a linear plot) provides some examples based on the sub-fermi electrostatic-potential shape of Fig. 3A. We could as easily select a shape that would give 95%, or 99%, of the total field-mass energy to be within the measured radius.

The present model would indicate that protons in a nucleus would repel one another at the $\sim$ 1 MeV level because of their charge. The fact that the addition of an electron's charge (by replacing a proton with a neutron) reduces the nuclear mass by $\sim$ 0.7 MeV supports this value.

Figure 4A presents the potential of a closely located electron proton pair ($V_p + V_e$) on a log-log plot. The absolute value of the negative electron potential is plotted for better comparison with the proton charge potential. Outside of the nucleus, the sum of the two potentials drops off as $\sim 1/r^3$, as should a dipole potential.

Figure 4B presents the electric-field-energy density of closely-located electron-proton pairs on a log-lin plot. Since the modeled potential is finite at $r = 0$, the electric field and its energy density is zero at this point. Beyond about 30 fm, the energy densities have little effect on one another. Within 10 fm, the electron is only a 'bump' on the side of a proton. Since the electron is moving around the proton, this bump is 'smeared' out and thus is reduced even more. To apply the uncertainty principle to an electron within this range of a proton would make little sense. The question arises, "at what point does a pair of fermions become a boson?"

When an electron comes within a fermi of a proton (with seriously overlapping energy densities), there is no means of identifying the electron as an individual entity. The strong fields and thus the high energy density are now between the pair. If stabilized in a weak interaction, the pair can become a neutron. This presents the next question: does the

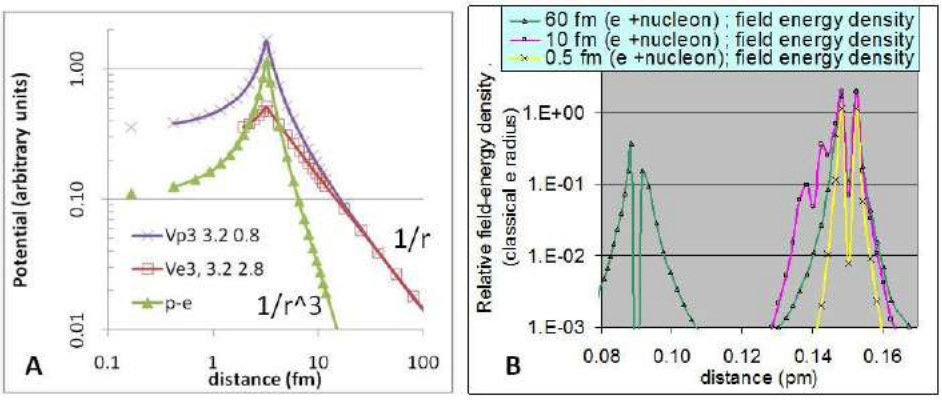

Figure 4. Proton 'shapes' for (A) potential and (B) field-energy densities of protons and electrons at various separation distances (0, 0.5, 10, and 60 fm).

pair of fermions become a boson before it is changed into another fermion, the neutron?

There are many unknowns about the nature and interactions of particles in the fermi range. Cold fusion may be able to contribute to the knowledge of this region. There is also an effect at larger distances that is seldom mentioned, because it is in the transition range between the more-stable nuclear and the atomic phenomena. The spin–spin interaction between intrinsic electron magnetic fields may be critical to CF models invoking the 'slow' collapse and fusion of linear or paired H molecules.

4. Electron spin–spin coupling

Electrons have magnetic moments ('**m**' in Fig. 5) resulting from the current (I) with (near) circular motion (rotation) of an effective-charge density. Magnetic fields (**B**) of electrons interact. These interactions are attractive when the magnetic moments of electron pairs are counter-aligned and repulsive when aligned. However, their effects are a 'mixed-bag' when misaligned. When the electrons are moving, the dynamic coupling is more complicated. When in orbital and/or relativistic motion, the near-field coupling is even further complicated.

The magnetic fields provide a dipole–dipole interaction. However, the amplitude of that interaction depends on the relative dipole-moment orientation and that is dynamic. In the far-field (atomic scale), the magnetic interaction is small relative to the Coulomb interaction; but it does provide ordering of the electron-shell filling. Because of the $1/r^4$ dependence of the dipole–dipole force, if the magnetic moments of two electrons are fully counter-aligned, then the

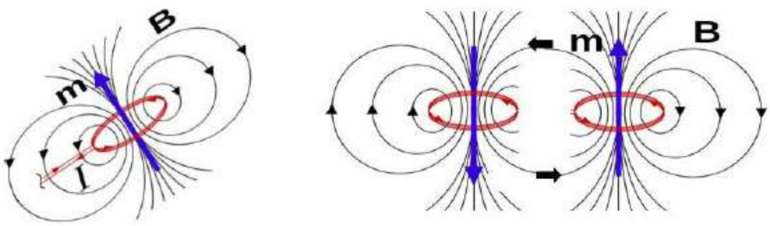

Figure 5. Magnetic fields from electron spin and their interaction.

spin–spin attraction [11] is comparable to the Coulomb repulsion when separated by the Compton radius. The attractive force will lower the total energy of the system providing an attractive potential (Fig. 6) and seeking to maintain the counter-alignment of electron spins. Nevertheless, the angular momentum of the electrons (orbital and spin) will prevent the continued counter alignment of the moments unless a resonance happens to provide such a mechanism.

In addition to the interaction of the electron's spin, external magnetic fields, and the proton magnetic moments (while small relative to those of the electrons) can influence the alignment of the electrons' moments.

Altering the relative alignment of the moments will change both the strength and direction of the interaction. This change can occur at each pass and will randomize the influence of the magnetic interaction. Furthermore, if the protons move closer together and the electrons move deeper into the protons' potential well, the increased electron velocity can introduce a relativistic contribution to the alteration of the spin vector directions. Thus, as the electrons move closer to the protons, such effects grow and the electron–electron interactions become less important relative to those with the proton(s). This should prevent an attractive magnetic potential from ever getting as strong as the Coulomb repulsion between the electrons. This attraction may even weaken with proximity to the proton(s) (or each other) so that it is small near the points of nuclear fusion or of deep Dirac orbits [10]. As a complex multi-body system, it may not have a steady-state solution for the equations of motion. But, it may be chaotic, rather than random. Nevertheless, the variable attractive potential between the electrons could greatly increase their time spent between protons only picometers apart and thus the attractive force drawing the protons together. Since the situation envisioned for this interaction is not steady state, but transient, perhaps just estimating the probability of aiding fusion by this mechanism is possible. However, longer-term interactions in deep-Dirac levels could be strongly affected by these magnetic dipole effects.

5. Summary

(1) The capability of changing H sub-lattice spacing is a potential answer to the cold fusion question of how to achieve H–H proximity and H–H penetration of a Coulomb barrier.

(2) For Coulomb potentials at nuclear distances:

   (a) The electron peak potential is probably limited by mass energy

   (b) The proton peak electrostatic potential is probably limited by its field-energy 'distribution'

(3) Electron spin–spin coupling may be critical to some CF models:

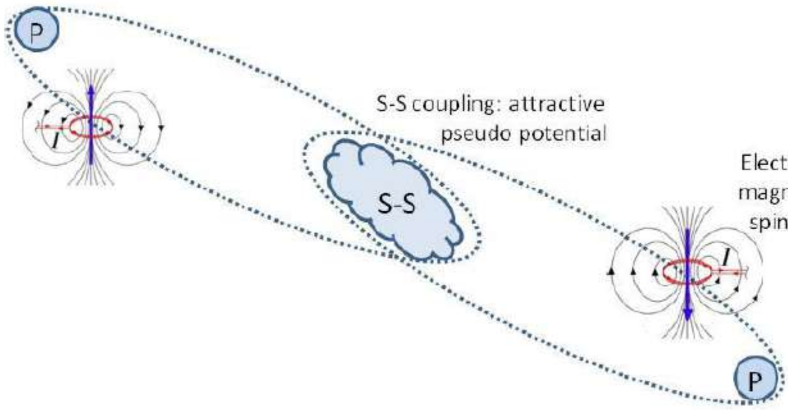

Figure 6. Magnetic field interactions producing a spin–spin attractive potential between electrons.

(a) Spin–spin attraction between electrons could exceed Coulomb repulsion for charge spacing within 300 fm.
(b) It provides an attractive pseudo-potential that is centered between the electrons.
(c) Spin alignment, perturbation, and relativistic velocities of magnetic dipoles in deep passes or orbits about protons make determination of spin–spin coupling difficult.
(d) The influence of these effects needs to be explored in terms of the Dirac equations and their anomalous solution.

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