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Research Article

Is the Nuclear Active Environment a Metals–Silicon–Boron–D_2 Alloy Enabling a Three-body Recombination between Deuteron and the Nuclei of D_2?

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Abstract

The Nuclear Active Environment (NAE) could be a site where three deuterons interact, e.g. a D_2 molecule and a deuteron, where the deuteron is pushed in between the two D nuclei, and form a hypothetical Efimov-like triple D state. Three-boson (Efimov) interactions can have a longer range than two-boson interactions. Two nuclei fuse to helium and the third is ejected in a three body recombination. In rare cases the result is tritium and helium-3. The NAE might be a semiconductor like silicon, known to incorporate hydrogen molecules. The NAE could perhaps be a compound like MoS_2, known as a possible substitute for platinum in electrolytic hydrogen evolution. The NAE might also be an alloy of metals with boron and silicon allowing occlusion of D_2 molecules sitting in a tight vice in a narrow lattice. Or the NAE might be palladium oxide/nickel oxide, which are hydrogenating catalysts. Or it might be a chemical compound such as silicon boride and titanium carbide where D_2 could sit in vacancies. A triple D might interact with lattice atoms according to the scheme $^{m}Me_n + (3D) \rightarrow {}^{m+2}Me_{n+1} + He$, which might lead to the formation of radioactive isotopes.
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1. Introduction

Electrolytic low energy nuclear reactions usually happen after a long delay, and with quite low reproducibility [1,2] although palladium/deuterium co-deposition may be a possible exception [3]. Some batches of palladium work, others do not [4]. During the long delay before LENR there are often substantial changes at the surface of the palladium electrode with several elements from impurities or the glass vessel such as silicon [1,2,5]. According to Storms, a nuclear active environment (NAE) must be established for low energy reactions to occur. Little is known about what characterizes the NAE, or what exactly is needed to obtain it [6]. Storms thinks that the NAE are cracks of a particular size allowing fusion and dissipation of energy by soft X-rays [7].

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The products of low energy nuclear reactions are primarily helium-4, much lower levels of tritium, and very low levels of neutrons [1,2]. This is most simply explained by three-body recombination [8–10] (or perhaps multibody [11,12]) among three deuterons, where two fuse to helium and the energy is converted by ejection of the third deuteron as proposed by Takahashi, according to the scheme:

$$\begin{aligned} \mathrm{D} + \mathrm{D}_2 \rightarrow (3\mathrm{D}) &\rightarrow {}^4\mathrm{He} + \mathrm{D} \;\; (23.8\,\mathrm{MeV}) \\ &\rightarrow {}^3\mathrm{He} + \mathrm{T} \;\; (9.5\,\mathrm{MeV}), \quad \text{rare.} \end{aligned}$$

In experiments with low keV deuteron bombardment on titanium deuteride energetic alphas and protons were observed by the groups of Kasagi and Takahashi [8,9,13]. This should not be possible with standard DD fusion, but it is compatible with triple D fusion models. In a palladium lattice the D atoms are almost 3 Å apart, and they do not easily get close because the positive charges are only lightly shielded by the outer electrons. Atoms in a D_2 molecule are 0.74 Å apart. Measurable fusion between D's requires a distance smaller than 0.2 Å [14]. However, according to Efimov [15] three bosons may interact over a longer distance than two bosons.

Efimov showed that three bosons, interacting resonantly, may form bound states, even if there is no bound state between two of the particles. For example, a helium trimer "molecule" exists but a helium dimer does not. In cases with several Efimov states, the second state is 22.7 times larger than the first, and the third state is 22.7 times larger than the second. The energy decreases with a factor $(22.7)^2$ between consecutive states. The first Efimov states have now been observed in atomic systems at very low temperatures [16,17]; The excited helium trimer is 150 Å large, 50 times the size of many molecules [18]. Usually coulomb repulsion negates the Efimov effect at a longer separation than the Bohr radius of 0.53 Å [18], but nobody knows whether shielding by electrons might modify this, so that virtual, short lived Efinov resonances might form between three deuterons brought close together. One could imagine that a deuteron injected between the deuterons of a lattice-trapped deuterium molecule could form a virtual Efimov-like state, followed by a collapse into ^{4}He and an ejected deuteron. This would require that the deuterium molecule not be able to move away; it must be fixed in a vice in the lattice.

2. Possible Nuclear Active Environments

An educated guess about the nuclear active environment would be a material that can incorporate deuterium molecules [19,20] in a tight lattice vice and at the same time be a good conductor. Deuterium molecules can primarily be found in semiconductors with Pauling-electronegativity close to that of hydrogen [21–23]. Good conductors such as most metals "alloy" hydrogen as single atoms. It may not be an easy thing to combine the two requirements in a single material. One possibility might be metallic glasses, e.g. Nickel–Chromium–Boron–Silicon or Palladium–Boron–Silicon [24,25]. The reason for including boron is that Palladium–Boron alloys tend to give better reproducibility in electrolysis experiments [4]. The reason for including silicon is that it is often found at the surface of electrodes after prolonged electrolysis [1,2]. Both compounds have electronegativities close to that of hydrogen. The metallic glasses solidify in complicated manners, in several different phases, some crystalline, some glasslike. The primary use of these alloys is as brazes for joining advanced materials like rotor blades for gas turbines. There are quite a number of them available as thin foils. The fact that these metallic glasses solidify in different phases may mean that one might have microenvironments with semiconductor character occluding deuterium molecules embedded in a conducting matrix.

Another possibility could be compounds like MoS_2 which should be able to intercalate hydrogen molecules between the layers [26]. MoS_2 is investigated as a possible platinum substitute for hydrogen production by electrolysis [27]. Perhaps deuterium molecules might be too mobile in pure MoS_2, but it might be possible to cross-link the layers with other atoms in order to keep the D_2 molecules in place.

Other possibilities might be palladium or nickel oxides. These compounds are commonly used as hydrogenation/dehydrogenation catalysts, meaning that there are equilibria between atomic and molecular hydrogen at their

surface. Kasagi's team observed that low keV D bombardment of deuterium in PdO gave fusion rates many times higher than D bombardment of D_2 gas or TiD [28]. Holmlid observed D–D fusions on an iron-oxide cracking, dehydrogenating catalyst after blowing away the electrons with a super-strong laser pulse [29].

Further possibilities might be conducting ceramics such as silicon boride or the dense lattices of titanium or zirconium combined with boron, carbon, or silicon [30]. Some of these ceramics are used as hardened surfaces on drills. The ceramics are tight lattices but with common vacancies, such as minus C. It is known that titanium-carbide dissolves more hydrogen than pure titanium [31]. The extra hydrogen might be sitting as molecules in the vacancies.

3. Transmutations/radioactivity?

If virtual triple-D states are large enough to "touch" the nuclei of the atoms in the lattice, one might find transmutations according to the scheme: $^{m}Me_{n}+$ (3D) $\rightarrow$ $^{m+2}Me_{n+1}+$ He. Or perhaps a lattice atom could be part of an Efimov state: ($^{m}Me_{n}+$ 2D) $\rightarrow$ $^{m+2}Me_{n+1}+$ D. This would fit with Biberian's finding of silver with a surplus of Ag-107 in one of Pons' palladium cathodes that had produced a great deal of excess heat [32]. The Ag-107 might originate from Pd-105 after capture of a deuteron. If this is a "viable" mechanism, then it should be possible to find radioactive isotopes at the surface of electrodes: Cu-60 from Ni-58, Ag-106 from Pd-104, V-49 from Ti-47, etc. Most of the isotopes mentioned are beta-emitters and have reasonable half-lives. There are numerous other possibilities, but many have either too short or too long half-lives to be easily observed. MoS_2 could be particularly interesting, because the many isotopes of molybdenum might be transmuted into isotopes of technetium, which are all radioactive. Chrome plating in D_2O might yield radioactive manganese.

4. Conclusion

Despite many years of labor, the LENR community still does not have a decisive experiment which can persuade mainstream physics and the public that low energy nuclear reactions are real and may become a useful source of energy. A rule of thumb says that it must be possible to demonstrate the principle in a source of energy in an afternoon in a high school laboratory, otherwise the problems of turning it into a practical energy source become insurmountable. A LENR experiment that could be done in an afternoon and end up with clicks on a Geiger counter is sorely needed. Perhaps it would be possible to find an alloy or chemical compound that could turn into a Nuclear Active Environment surface in a few hours.

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