Where and How LENR Occur

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The occurrence of LENR involves two separate considerations: (1) the location where reactants come together, and (2) the mechanism by which the nuclear reactions occur. Understanding, and also the practical reproducibility and control of LENR, require attention to both where and how LENR happen.

Where: The locations and conditions needed for production of LENR, what Storms called the Nuclear Active Environment (NAE) [1], have received much attention over the decades. Both the interior and surfaces of materials have been considered, with frequent attention to defects. The interiors of real lattices range from being **highly pure and perfect** with thermal vacancies (like silicon crystals grown for chips) to other **pure but defective crystals** with 0-D point defects (single vacancies or small clusters of vacancies), 1-D line defects (various dislocations and also vacancy tubes in Super Abundant Vacancy or SAV materials), 2-D planar defects (internal grain and twin boundaries, and external surfaces), and 3-D defects (including gaps, cracks and voids), to **impure crystals** (with interstitial or substitutional impurities) to **alloys** (of many kinds). There is a similar range of defects on surfaces, including 0-D point structures (surface vacancies or adatoms), 1-D defects (notably ledges), 2-D defects (such as the surface itself and incomplete overlayers) to 3-D defects (including gaps and cracks). Storms favors cracks on and in materials [2]. Miley has touted dislocations as the NAE [3]. Staker apparently believes that LENR occur within tubes of vacancies in SAV materials [4]. This paper considers grain boundaries and surfaces as the NAE. Both of these 2D structures are very common, and have open characteristics. Those two features favor both high accumulation and facile motion of deuterons or protons into and within materials on scales ranging from the macroscopic to the nanometer scale. High loading and high fluxes of deuterons are both known empirically to favor production of LENR.

How: The physical mechanisms for nuclear reactions also require detailed consideration. Numerous theories have been advanced to explain how LENR occur, but most of them are incomplete [5]. One of the more complete LENR theory was advanced by Kálmán and Keszthelyi [6]. It involves a three-body catalytic mechanism, and standard second-order Quantum Mechanical calculations. Their published numerical results have yet to be validated, but their mechanism agrees well with results from significant LENR experiments. For example, some experiments have shown that LENR power varies with the square of the degree of loading. Many experiments have shown the value of a flux of deuterons or protons. The Kálmán -Keszthelyi mechanism agrees with these and some other LENR observations.

This paper will review laboratory LENR data which supports both possibilities: (1) LENR tend to occur near grain boundaries within lattices, and also on the surfaces of lattices, and (2) the three-body catalytic mechanism is a leading candidate for the understanding of LENR. Experiments to test both perspectives will be recommended. Significant LENR data that does not clearly align with the two possibilities will also be examined. Such data challenge the perspective of this paper.

[1] E. Storms, "The nature of the energy-active state in Pd-D. Infinite Energy, Issue 5 &6, p. 77 (1995)
[2] E. Storms, "An Approach to Explaining Cold Fusion", Proceedings ILENRS-12, Paper 6-1 (2012)
[3] G. H. Miley *et al.,* "Use of D/H Clusters in LENR and Recent Results from Gas-Loaded Nanoparticle-type Clusters", J. Cond. Matter Nucl. Sci., vol. 13, pp. 411–421 (2014)
[4] M. R. Staker, "A model and simulation of lattice vibrations in a superabundant vacancy phase of palladium deuterium", Modelling and Simulation in Mat. Science and Eng., vol. 28, 065006 (2020)
[5] D. J. Nagel, "Expectations of LENR Theories", J. Cond. Matter Nucl, Sci., vol. 26, pp.15–31 (2018)
[6] P. Kálmán and T. Keszthelyi "Nuclear processes in solids: basic 2nd-order processes", arXiv:1303. 1078v3 (24 Jan 2017) and "Forbidden nuclear reactions", Physical Review C, vol. 99, 054620 (2019)