LOW ENERGY NUCLEAR REACTIONS: 2007 UPDATE

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Abstract

This paper presents an overview of low energy nuclear reactions, part of the field of condensed matter nuclear science. The review presents some of the reasons why the subject of "cold fusion" was viewed as a mistake and why it now is recognized as a legitimate science.

This update includes the broad array of nuclear ash and effects observed in LENR research, as well as the brief details of a reproducible experiment. A model that may explain the effects not as fusion or fission, but based on weak interactions is reviewed.

Keywords

cold fusion, low energy nuclear reactions, condensed matter nuclear science, Fleischmann, Pons, palladium, deuterium, electrolysis

The Problematic History of Cold Fusion

Cold fusion is the popular term for the field of research that originated from an electrolysis experiment using the elements palladium (a heavy metal) and deuterium (an isotope of hydrogen). The experiment was first performed by Dr. Martin Fleischmann and Dr. Stanley Pons at the University of Utah in 1984, although related work had been performed as early as 1920. Fleischmann and Pons claimed an electrochemical method of generating nuclear energy, in a way that was previously unrecognized by nuclear physicists.

The public introduction of the Fleischmann-Pons work arrived with numerous problems.

1. Fleischmann and Pons had great difficulty in repeating their experiment.
2. At the time of their startling announcement, they had no other replicators to provide independent confirmation of their claims.
3. They had weak corroborative evidence to support their claims of a nuclear reaction.
4. Their gamma/neutron data was in error.
5. Their claim appeared to contradict the laws of physics.

18 Years of Progress

Two hundred researchers from 13 nations have continued the investigation started by Fleischmann and Pons. The research has been discussed at 12 international conferences, as well as 28 local conferences in Italy, Japan and Russia. Papers have been published in many of the conference proceedings as well as in 55 peer-reviewed journals.

Highlights of the field include:

1. Claims by several researchers of very high repeatability [1,2]
2. At least one narrowly defined experiment that is reproducible on demand [3]
3. Many experiments that, despite the use of broad and varied protocols and parameters, demonstrate similar replications of excess heat and heavy element transmutation [4]
4. Expansive corroborative nuclear evidence [5]
5. A proposed theory that may explain the LENR phenomena [6]

Overview of the Field of Condensed Matter Nuclear Science

The term “condensed matter nuclear science” (CMNS) has been adopted by researchers studying the phenomena called low energy nuclear reactions (LENR), historically known as cold fusion.

A key component of these phenomena is the reliance on condensed matter, such as palladium, as an integral component of these reactions. In some circumstances, liquid media act as the condensed matter and take the place of the host metals.[7]

CMNS studies nuclear effects in or on condensed matter, unlike thermonuclear fusion research, which is performed in a plasma without a host material.

CMNS is an inter- and multidisciplinary research field encompassing nuclear physics, condensed matter physics, surface physics and chemistry, and electrochemistry. CMNS applications involve many other fields, as well, including nuclear engineering, mechanical engineering, electrical engineering, laser science and engineering, material science, nano-technology and biotechnology.

Other less-common terms exist; they include "chemically assisted nuclear reactions," "solid-state nuclear reactions," "cold nuclear fusion" and "low energy nuclear transmutation."

Within the subject of LENR, two groups of reactions are recognized. (See Figure 1) The first is what traditionally has been called "cold fusion," a set of reactions that takes place with palladium and deuterium, yielding excess heat and helium-4 as its predominant products. Numerous proposed mechanisms exist, however no theory is generally accepted. The claim of fusion is still considered speculative and, as such, is not an ideal term for this work.

The LENR field includes another group of reactions whose primary result is not energy release but transmutation of heavy elements. This group shows a wide assortment of nuclear reactions that may occur with either hydrogen or deuterium.

Many Methods to Create Low Energy Nuclear Reactions

Researchers report ten methods claimed to produce either anomalous power or nuclear products. These include methods of electrolysis, deuterium gas and acoustic cavitation. [4]

Nuclear Ash and Effects

A wide variety of nuclear ash; telltale products and effects from these reactions provide evidence of nuclear reactions. (See Figure 2.)

Dominant products claimed in the D/Pd environment are heat and helium-4. Several researchers claim to have measured close correlations of the two. [8,9,10] Other products and effects that are claimed are tritium evolution [5][5] and neutron flux [11], but these are rare and only at low magnitudes. Recent experiments by the U.S. Navy's Space and Naval Warfare Systems Command Center in San Diego, Calif., group suggests the occurrence of low energy neutron fluxes.[12]

Heavy element transmutation has been reported as a major effect in the H/Pd environment and, to a lesser degree, in the D/Pd environment. [13,14]

A variety of effects that, by themselves, do not imply nuclear reactions have been reported. However, with consideration of the very low input energies, four watts, for example, the observations of X-rays, melting and vaporization of metals suggest the occurrence of nuclear reactions. [12]

The Materials Science Challenge of Excess Heat

Excess heat has been difficult to repeat and consistently reproduce. The conditions required to demonstrate excess heat are generally well-understood; however, they are not easy to achieve. Most LENR methods have three parametric requirements:[15,16]

1. High atomic loading ratio of D into Pd. In most conditions, D/Pd > 0.90 is the minimum threshold required to produce an excess heat effect, and D/Pd=1.0 consistently yield excess heat if other parametric requirements are met. Preparation of Pd so that it can contain and retain such a high loading of D is not easy. This factor is one of the greatest challenges of the field. Researchers with extensive experience in metallurgy have reported the best success.
2. A high electrical current density in the cathode is required. In most conditions, 250 mA/cm2 is required.
3. The third requirement is for a dynamic trigger to impose a deuterium flux in, on or around the cathode. The experiments generally must have a trigger that takes them out of equilibrium. Some triggering examples are a rapid increase in current, temperature, external electric and magnetic fields or irradiation with a low-power (30mW) laser.

A Reproducible Experiment

Researchers at the U.S. Navy SPAWAR have developed a unique experiment that appears to be reproducible on demand.[3] Instead of using a traditional palladium cathode, they electrochemically deposit palladium, simultaneously with deuterium, onto a substrate of nickel, silver, platinum or gold.

The use of the co-deposition electrolysis method achieves the required D/Pd atomic ratio nearly instantly and consistently, thereby circumventing the problem of attaining high loading with solid palladium cathodes.

The SPAWAR researchers use CR-39 nuclear track detectors to record the emissions of what appear to be charged particles. These detectors permanently record the history of nuclear emissions from the experiments and have shown extremely high track densities and signal-to-noise ratios.

Initially, the researchers were looking for evidence of alpha particle emission; however, they have begun to see tracks coming through the detectors, which suggest that neutron emissions are causing recoil reactions.

The researchers have used the nuclear track detectors both inside the electrolytic cells (wet experiments) and outside the cells, protected by thin membranes (dry experiments).

So far, optical analyses show the visual characteristics nearly identical to those you would expect to see from tracks caused by particle emissions. Some gamma data have been taken,[17] and investigations are under way to characterize and quantify the energies responsible for these tracks.

A Nonfusion "Cold Fusion" Theory

In 2005, Allan Widom and Lewis Larsen began publishing papers [6] that presented a new theory to explain the experimental anomalies observed in "cold fusion" experiments. Their theory claims that these anomalies are not from a fusion reaction, which would involve the strong force, but from other low energy nuclear reactions that involve weak interactions, namely neutron formation from electrons and protons/deuterons, followed by local neutron absorption and subsequent beta-decay processes.

Highlights of their claims:

1. Based not on fusion or fission but weak interactions.
2. Explains most of the well-accepted experimental data in "cold fusion" field
3. Matches Miley experimental transmutation data
4. Suggests an explanation for Iwamura transmutation effect
5. Explains light and heavy hydrogen experiments
6. Requires no "new physics"

Conclusion

Significant questions face society regarding this research: a) Are LENRs genuine nuclear reactions? b) If so, is there a release of excess energy? and c) Are transmutations possible?

If the answers to these questions turn out to be positive, the next questions to ask are d) Is the energy release cost-effective and e) Are the transmutations useful?

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Appendix: Resource Information

The New Energy Times Resource Index

This index provides numerous articles on the basic facts and the controversy, the scientific evidence, the famous press conferences, the reasons that critics thought it was all a mistake, and other related historical investigations.

http://newenergytimes.com/start

New Energy Times Magazine

This online magazine publishes six times per year.

http://newenergytimes.com/news

The LENR Online Library

The library contains 3,400 references to related papers, as well as 570 papers downloadable at no cost.

http://lenr.org

The Beaudette Archive on Cold Fusion

The archive (Accession #2297) is located in the J. Willard Marriott Library of the University of Utah, Salt Lake City, Utah. It comprises a collection of 1,800 papers, 700 quotations, and 40 interviews from March 1989 through 2005. Also included are the proceedings for the International Conferences on Cold Fusion Nos. 1-11 and technical reports from other conferences, such as the EPRI/NSF meeting of October 1989.

International Society for Condensed Matter Nuclear Science

The International Society for Condensed Matter Nuclear Science is an independent, international nonprofit organization registered in England which represents and supports researchers in the field of condensed matter nuclear science. ISCMNS organizes scientific meetings, supports communication within the scientific community, and provides recognition for outstanding achievements in the CMNS field.

http://iscmns.org

References

[1] Violante, V., et al. Study Of Lattice Potentials On Low Energy Nuclear Processes In Condensed Matter. Proceedings of the Tenth International Conference on Cold Fusion, World Scientific Publishing Company; 2003.

[2] Miles, M. Thermal and Nuclear Aspects of the Pd/D2O System: Vol. 1 A Decade of Research at Navy Laboratories, ed. S. Szpak and P.A. Mosier-Boss. SPAWAR Systems Center, San Diego, U.S. Navy; 2002.

[3] Szpak, S., et al. Further Evidence Of Nuclear Reactions In The Pd/D Lattice: Emission Of Charged Particles. Naturwissenschaften 2007; DOI 10.1007/s00114-007-0221-7.

[4] Storms, E., The Science Of Low Energy Nuclear Reaction, World Scientific Publishing Company; 2007.

[5] Krivit, S.B., and Winocur, N., The Rebirth of Cold Fusion: Real Science, Real Hope, Real Energy. Los Angeles:Pacific Oaks Press;2005.

[6] Widom, A., Larsen, L. Ultra Low Momentum Neutron Catalyzed Nuclear Reactions on Metallic Hydride Surfaces. European Physical J. C - Particles and Fields 2006; 46(1):107.

[7] Koldamasov, A., et al. Observation and Investigation of Nuclear Fusion and Self-Induced Electric Discharges In Turbulent Liquids. Proceedings of the Twelfth International Conference on Condensed Matter, World Scientific Publishing Company; 2005.

[8] M. Miles, et al. Correlation of Excess Power and Helium Production During D2O and H2O Electrolysis Using Palladium Cathodes. J. Electroanalytical Chemistry 1993;346:99.

[9] McKubre, M., et al. The Emergence of a Coherent Explanation for Anomalies Observed in D/Pd and H/Pd System: Evidence for 4He and 3He Production. Proceedings of the Eight International Conference on Cold Fusion, Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy 2000.

[10] Storms, E. An Update of LENR for ICCF-11. Proceedings of the Eleventh International Conference on Condensed Matter Nuclear Science, World Scientific Publishing Company 2004.

[11] Mizuno, T. Nuclear Transmutation: The Reality of Cold Fusion. Bow, New Hampshire: Infinite Energy Press; 1998.

[12] Mosier-Boss, P.A., et al. Pd/D Co-Deposition: Excess Power Generation and Its Origin. Proceedings of the 233rd ACS National Meeting and Exposition, Chicago, IL 2007.

[13] Miley, G.H., Shrestha, P. Review of Transmutation Reactions in Solids. Proceedings of the Tenth International Conference on Cold Fusion, World Scientific Publishing Company 2003.

[14] Iwamura, Y., et al. Elemental Analysis of Pd Complexes: Effects of D2 Gas Permeation. Japanese J. of Applied Physics 2002;41:4642.

[15] McKubre, M.C.H., et al. Excess Power Observations in Electrochemical Studies of the D/Pd System; The Influence of Loading. Proceedings of the Third International Conference on Cold Fusion. Universal Academy Press, Inc., Tokyo, Japan 1992.

[16] Hubler, G. Anomalous Effects in Hydrogen-Charged Palladium – A Review. J. of Surface & Coatings Technology 2007 (10.1016/j.surfcoat.2006.03.062)

[17] Forsley, L., et al. Time Resolved, High Resolution Gamma-Ray and Integrated Charge and Knock-on Particle Measurements of a Pd:D Co-deposition Cell. American Physical Society March 2007

FIGURE CAPTIONS

Figure 1. Relationship of low energy nuclear reactions, condensed matter nuclear science, and the two groups of LENR reactions

Figure 2. Nuclear ash; effects and products observed in LENR experiments

FIGURES

Figure 1. (enclosed as attachment Krivit-Figure-1-bw.jpg)

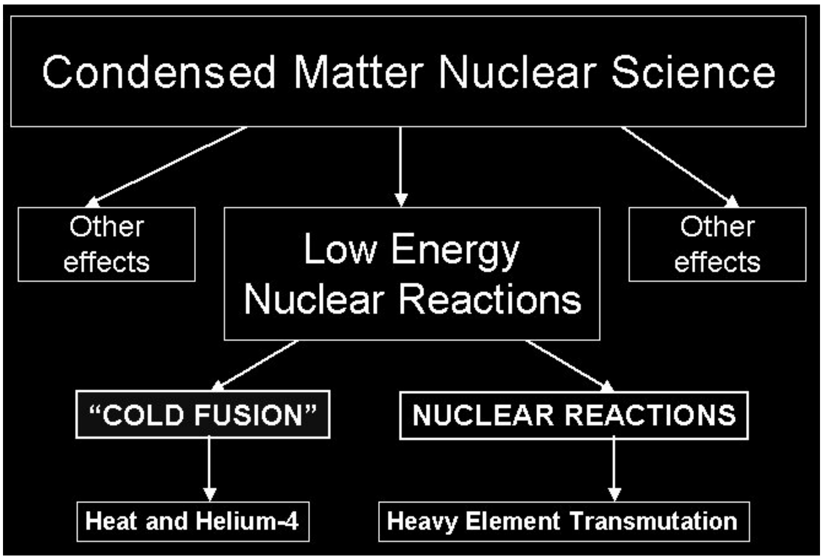

Figure 1 color [for Web]. (enclosed as attachment Krivit-Figure-1-4-color.jpg)

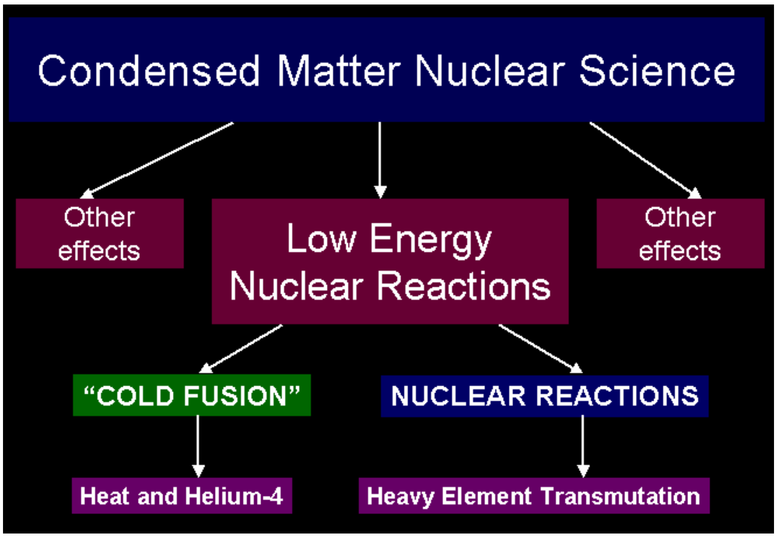

Figure 2. (enclosed as attachment Krivit-Figure-2-bw.jpg)

Nuclear Ash

Products/Effects	D/Pd	H/Pd
Heat	10^{12} events/s/W	Minor
Helium-4	10^{11} events/s/W	n/a
Tritium	10^{4} events/s	n/a
(Fast? Slow?) Neutrons	Uncertain	Uncertain
Charged Particles	Yes	Uncertain
Heavy Element Transmutation	Minor	Major
Gamma-Rays	Yes	Unknown
X-Rays	Yes	Unknown
Hot Spots on Cathodes	Yes	Unknown
Craters, Melting, Vaporization	Yes	Unknown

Figure 2 color [for Web]. (enclosed as attachment Krivit-Figure-2-4-color.jpg)

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Products/Effects	D/Pd	H/Pd
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